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President's Page

On the Role of IUGG in Advancement of Geophysics

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In a few weeks the Twelfth General Assembly of the International Union of Geodesy and Geophysics (IUGG) will open in Helsinki. Scientists from every continent will gather there for a variety of purposes but principally to hear the results of research, to exchange views, and to talk about new possibilities and future studies in geophysics. There will be geodesists, hydrologists, geomagneticians and aeronomists, meteorologists, oceanographers, seismologists, volcanologists, geochemists, and others from specialized fields of chemistry, physics, and mathematics relating to geophysics. This will be the first General Assembly of IUGG since the close of the International Geophysical Year; also, the first since the successful launching of sputnik and the discoveries made possible by subsequent artificial satellites. There will be a wealth of new data, new conclusions, new theories, and new questions to discuss.

The triennial Assembly offers unique opportunities for exchange of knowledge across so-called boundaries separating the several Earth sciences. In recent years there have been increasing numbers of cases in which advances in science have come from transfer of knowledge and techniques from one field to another. The trend toward universality in science lends emphasis to the importance of exchange of learning and transfer of principles and techniques from one discipline to others where they are applicable. As the range of man's knowledge increases and the compulsions for further advances become more pressing, the dissemination of scientific information becomes more important and more difficult. Ways that satisfied needs during leisurely and less complex times

in the past will not be adequate for the future.

When the IUGG was organized, it was planned for the General Assembly and technical sessions of the Associations to meet every third or fourth year. This seemed sufficiently frequent as viewed in the 1920s. There were factors other than the less rapid accumulation of new findings in the Earth sciences in those days as compared with the present. Travel was slower and geophysicists from far places had difficulty in finding the time and money for more frequent journeys to General Assemblies. But now the circumstances are quite different. Research has expanded many fold in scope and productivity. Emphasis on advancement of science and prompt exchange of new knowledge is much greater. Air transportation has reduced the time required for travel and for many scientists even the funds for financing attendance at far-away meetings and conferences are easier to come by! In view of these changes should the IUGG, pursuant to its pronounced objectives, plan for more frequent meetings of its associations or is the purpose of a forum for international scientific intercourse served by one or more of the other media for exchange of information that might now be utilized? This is just one of the many questions that pertain to the future role of the IUGG in the advancement of geophysics.

Like the aims and purposes of most scientific associations, the objectives of the Union are comprehensive and farsighted. If they were to be carried out literally and completely, it would be necessary to organize much more extensively and to expand staff, facilities, and activities. Stated very briefly, the stated aims

of the Union are to promote the study of the Earth, oceans, and atmosphere throughout; to initiate, facilitate and coordinate geophysical research; to provide international meetings for discussion and publication of results of research; to promote coordination among all related scientific associations; to furnish advice on practical problems in geophysics; and to sponsor and coordinate permanent services for collection, analysis, and publication of geophysical data. Probably few delegates to the Twelfth Assembly would wish to see the IUGG attempt these goals in an 'all-out push.' In fact, there are at least a few who would oppose any great change in the present loose Associations and their open forums, free from the disadvantages of big organization and the pressures that inevitably develop from intensive planning and coordination and the impersonal constraints that grow out of energetic organization.

In Rome in 1954 and in Toronto in 1957, one heard occasional discussions in the corridors, around dining tables, and elsewhere, on reorganization of the IUGG and the need for more direction and coordination in the accomplishment of its aims if these responsibilities were to be carried forward with reasonable progress and their absorption by one or another more enterprising organization were to be forestalled.

In earlier times scientific progress was looked upon as a matter of natural evolution, more or less. Although there doubtless has always been an appreciation of human welfare among scientists and an awareness of the benefits of science to mankind, and consequently some sense of responsibility for advancement of science, these attitudes have now become prevalent and advancement of science has come to be regarded as more urgent. With these attitudes comes the assumption that leading scientific societies will do something about the matter. It is entirely appropriate therefore that delegates to the Twelfth General Assembly give some thought and discussions to the new challenges. One could suggest many things that are reasonable and practical. The possibility of more frequent meetings of the Associations has been mentioned. More frequent sponsorship of 'summer seminars,' suggestions for attracting a larger number of young men and women into careers in science, more active collaboration in meetings and fuller exchange of information with affli-

ated scientific associations are other practical possibilities. The growing bulk of scientific publications brings need for better reference facilities and for new abstracting services. A few publishers foresee the time when many important scientific papers will not appear in journals but will be processed into reduced printed form for deposit in central archives where they may be procured in reproduced readable form when called for by persons who are directly interested in the full text. This proposal incidentally has already evoked strong adverse opinions.

Another underdeveloped field for international exchange of geophysical information and plans is found in the present status of working arrangements between world organizations.

The IUGG has a working agreement with the World Meteorological Organization to promote coordination of 'programs' and exchange of information. If the two organizations were to put into effect the words of these agreements it would require an increase by an order of magnitude or more in the work now being done in this sector. Without any risk of being overzealous one could suggest many ways in which more activity in these inter-agency functions would be beneficial scientifically. As an illustration the national operating organizations of meteorological services under the WMO in their decisions about location of stations in their synoptic weather networks should welcome the findings of research aired in the forum of the IUGG as regards the most serious deficiencies in data for research purposes. While it is true that recommendations in such matters now come to attention of the directors of national meteorological services by direct communications from research geophysicists not only those associated with their own staffs but also from scientific colleagues in other lands, the network planning could be improved if data deficiencies were considered in a more organized manner. This is just one of hundreds, perhaps thousands of subjects, in which better exchange of information would contribute to advancement of the sciences. Another illustration: In planning expeditions or new facilities such as oceanographic vessels for gathering geophysical data in remote regions, there are occasions when several sciences could benefit if the means for coordination of interests and plans were more effective and this could

be done without loss of desirable features of voluntary action and freedom of choice. Similar ways for more active cooperation with kindred scientific associations are awaiting attention and development. These subjects involve also working arrangements with ICSU, CIG, and special bodies like SCOR and in the past CSAGI which act in some respects as executive agents in broad planning for the gathering of geophysical data.

We may be quite sure that as science be-

comes more predominant in world affairs the role of international association in geophysics will be increasingly important. The Twelfth General Assembly of the IUGG is a timely place not only for consideration of the many exciting technical papers that will be presented there but also for discussion of inevitable changes that will take place in the role of the IUGG. Wise and deliberate guidance in shaping the things to come as regards scope and activities of the Union would be well worthwhile.

The Survey of the Geomagnetic Field in Space

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Introduction—The scientific progress of man has often been identified with the improvement of his description and understanding of his environment, both on a macroscopic and microscopic scale. Thus some features of the Earth's crust, the oceans, and the atmosphere, have been described and discussed, but in the earth sciences there remains a considerable void in our perception and understanding of these regions. The present paper will be concerned with only one facet of this huge and fascinating complex, the Earth's geomagnetic field near the Earth and in the surrounding space. As in the case of the gravitational field measurements of this field were available until recently only near the Earth's surface.

The description of the Earth's surface magnetic field as a global feature dates back to the fifteenth century, when the instrument makers of Nuremberg and Columbus found that the compass did not usually point true north. By 1701 ocean and land magnetic measurements by compass sufficed to permit the British astronomer Edmund Halley to draw the first world magnetic chart. He pointed out, however, that it would soon become out of date, because of the rapid changes of compass direction per decade. In fact, users of magnetic charts for navigation, surveying and other engineering purposes have in recent years been revising such charts about every ten years, even though many regions of the Earth have not been resurveyed this often. These secular changes in the charts arise because of ceaseless modifications of the fluid motions within the Earth's central molten core, according to our more recent modern speculations. A very small part, however, arises from changing electric currents flowing in the Earth's atmosphere and beyond [Chapman and Bartels, 1940].

Geomagnetic measurements—The geomagnetic field has both direction and magnitude at any point. Thus the variation or direction of the compass, or magnetic declination, is meas-

ured from true north and reckoned positive, around by east, the downward (or positive) dipping of a magnetized needle below the horizontal plane (or inclination), and magnitude of the field define it completely, at a point in space and time. These parameters are customarily the ones measured aboard aircraft and non-magnetic ships at sea. On land, measurement of the component of the field intensity parallel to the earth's surface, or horizontal intensity, is usually substituted for the total intensity. Measurement of values of angle to the nearest tenth of a minute of arc and of intensity to 10^{-8} cgs unit or gauss are usually quoted. Instruments are intercompared with national and international standards.

Early surveys and theory—Early surveys to 1900 were conducted incidental to many expeditions and to the travels of interested scientists. In addition to Columbus, other notable contributors included Halley, who made measurements of declination over the Atlantic Ocean in 1698-1699, and von Humboldt, who traveled to France, Cuba, Mexico, Peru and the United States shortly after 1800. The theory of observational procedures owes much to Poisson, who developed the concept of the potential of magnetized bodies, and to Gauss who developed a scheme for measuring the magnetic intensity in 1832, and the mathematical theory of spherical harmonic analysis of the field in 1838.

A number of problems of scientific and practical interest require for their solution a knowledge of the Earth's main field and of its changes with time. The origin of the main field has been sought for several centuries. Recently it has come to be believed that the fluid motions in the Earth's liquid conducting core and that the changes in these fluid motions with time generate huge electric currents there, which in turn provide the main field and its secular change. The Earth's main field is hence related to major terrestrial structures and their geological history. When this field is better understood as

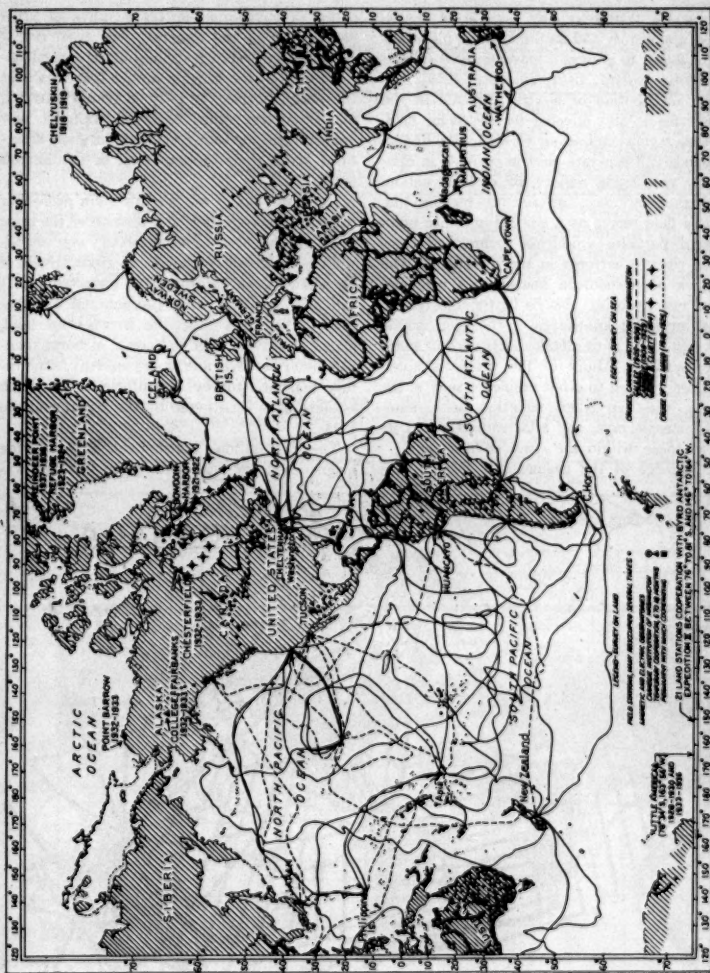


FIG. 1—World magnetic survey, Carnegie Institution of Washington, 1905-40; courtesy, the Carnegie Institution of Washington

a planetary feature it may likewise be indicative of the history and nature of other planetary bodies found to possess a magnetic field [Elsasser, 1950; Bullard, 1949; Runcorn, 1956].

The distribution of electric currents in the ionosphere is also affected by the main field. In some regions ionized air blown by the upper-air winds will generate electric currents in electrically conducting regions, by dynamo action. In higher latitudes, in auroral regions, the Earth's field serves as a guiding influence upon charged particles producing aurora and associated electric currents in the ionosphere. The complex of phenomena known as a magnetic storm can probably also be better understood, if an improved knowledge of the geomagnetic field and of its more detailed attitudes in space were available. Many of the problems noted are closely linked to other problems, such as the aurora, the Van Allen radiation belts, ionosphere, cosmic rays, and solar radiation and its disturbances, within the space environment.

Knowledge of the geomagnetic field is also

useful in navigation, in the geophysical prospecting for oil and minerals, and in surveying and other engineering applications. In geophysical studies of the Earth's surface traverses over the ocean surface and by airplanes carrying magnetometers afford especially valuable new opportunities revealing evidence of great structural shifts from time to time in the Earth's crust.

Later surveys of the Earth's main field—For reasons of convenience, and because of the large scale of the operations involved, any world-wide geomagnetic survey near ground level is of necessity an international undertaking. It can only be done with international cooperation. It involves magnetic surveys on land, magnetic surveys over the ocean, airborne magnetometer surveys, and, more recently, exploratory magnetic survey measurements by Earth satellite have been made by the USSR and the USA.

The first serious attempt at a world-wide magnetic survey was that of the Carnegie In-

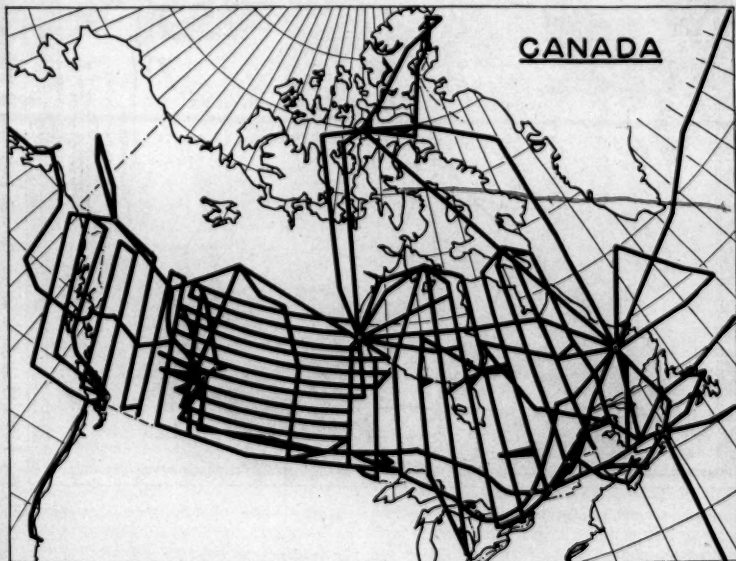


FIG. 2—Dominion Observatory, three-component airborne magnetic surveys, 1953-1958

stitution of Washington, through its Department of Terrestrial Magnetism, during the first quarter of the twentieth century. There were over 50 survey expeditions over land areas of all continents except Europe, and there was partial coverage of the Arctic, and of a small part of the Antarctic as well. A freighting vessel, the *Galilee*, was operated for a few years after 1900 as a magnetic survey vessel on three cruises over the oceans. It was followed soon after by the non-magnetic ship *Carnegie*, which operated on all oceans until 1929, undertaking a total of seven cruises, when it was destroyed by fire. The *Carnegie* and *Galilee* combined surveyed nearly 500,000 mi of the oceans of the world (Fig. 1). The surveys of the Carnegie Institution also terminated near this time, though a few land magnetic surveys of limited scope were made here and there until about 1945. This was a major contribution to geomagnetism, with coverage over vast areas of the globe where magnetic measurements had not previously been made [Bauer, 1912; Bauer and Fleming, 1915; Bauer, Peters, Fleming, Ault and Swann, 1917; Bauer, Fleming, Fisk, Peters and Barnett, 1921; Ault, Mauchly, Peters,

Bauer, and Fleming, 1926; Fisk and Sverdrup, 1927; Wallis, Green, and Fleming, 1947]. Many other expeditions and some cruises have also been made [Chapman and Bartels, 1940].

World magnetic charts have been prepared by the British Admiralty [Leaton], the U.S. Coast and Geodetic Survey and U.S. Hydrographic Office, the USSR [Altshuler, Vints, Mal'tseva, Chuguryan, and Shlyakhtina, 1955]. A study for 1945, preparatory to the issue of charts by the U.S. Hydrographic Office, was given by the Carnegie Institution of Washington [Vestine, Laporte, Lange, Cooper, and Hendrix, 1945; Vestine, Lange, Laporte and Scott, 1947].

After the loss of the *Carnegie*, the British Admiralty constructed a replacement, the *Research*, launched in 1939. Because of World War II, its engines were never completed and for reasons of economy it was broken up in 1954.

The USSR also constructed a non-magnetic ship, the *Zarya*, launched in 1956. It has since made a number of traverses over all major oceans, and is filling in important gaps in information over the oceans. Since the oceans comprise the major surface area of the world it

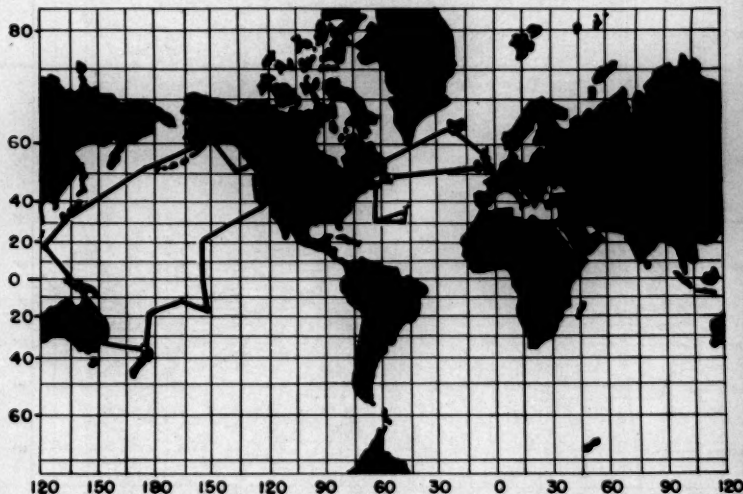


FIG. 3—Three-component airborne magnetic surveys, flights outside Canada, 1954 and 1958

is perhaps doubtful if only one such ship, operating continuously, can suffice to serve the world's needs for magnetic secular change and main field information. Because the operation is slow and expensive it is sometimes argued that such surveys are more conveniently done by instruments carried aboard an airplane. There is little doubt that this is true, but to this date, as far as the writer is aware, measurements for secular-change purposes are more accurate when taken by magnetometer aboard a non-magnetic ship. It is therefore desirable to have more than one ship surveying the oceans, and it is clear that surveys by aircraft and by ship are complementary rather than mutually exclusive. In view of the rapid improvement of airborne magnetic instruments and their control, the situation may change in a decade or two. But at the present time and for some time to come, both kinds of surveys are essential.

Substantial progress in surveying the oceans by airborne magnetometer has already been made, particularly by the U.S. Navy Hydrographic Office and the U.S. Air Force, in coop-

eration with the U.S. Coast and Geodetic Survey. A survey of all components in the Canadian Arctic, was completed, and also for the North Atlantic. A part of this work was done cooperatively with activities in Canada, where extensive surveys using magnetometers similar to those of the U.S. Navy were employed. Much of Canada was covered in recent years, and also the adjacent waters well into North Pacific regions. Extensive airborne surveys in Great Britain and Australia have also been made. In addition, many thousands of miles have been covered using airborne magnetometers for geophysical prospecting, in all continents, including Antarctica, and several score of different magnetometers for this purpose of several patterns have been constructed. These magnetometers measure only total magnetic intensity, and the aim is usually mainly that of delineating geomagnetic anomalies caused by crustal rocks. The description of such anomalies on a world-wide scale would be a most interesting and valuable project, but a costly and time consuming undertaking, although extensive cov-

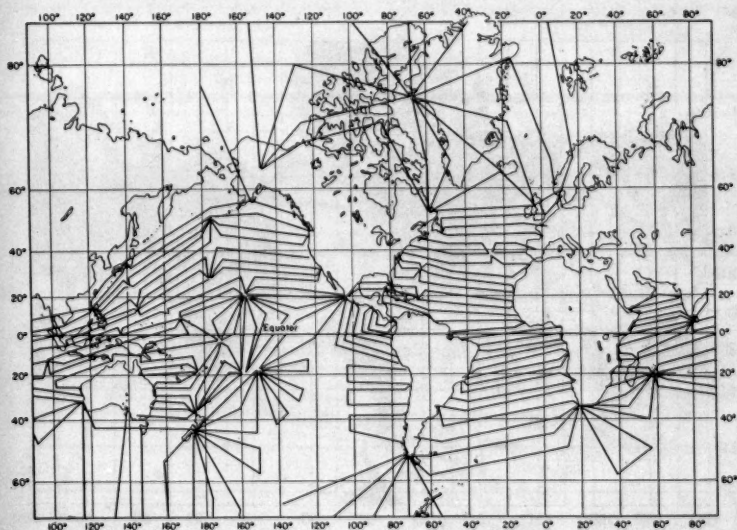


FIG. 4—U. S. Navy Hydrographic Office airborne geomagnetic survey plan Project Magnet

erage of special regions in the USSR, the United States, Canada, and Australia has already been provided. In the present paper attention will be confined only to the already very substantial project of covering the broader features of the geomagnetic field and its secular change, so that only the larger anomalies in field pattern are considered.

Airborne magnetometer surveys over the oceans—Examples of surveys already made or planned will next be considered. Figures 2 and 3 show traverses made by airborne magnetometer in Canada and adjacent regions by Serson and his colleagues of the Dominion Observatory in cooperation with the Royal Canadian Air Force. It will be noted that surveys have been made both over land and sea. Surveys such as these have already been incorporated in World Magnetic Charts for 1955 issued by various mapping agencies.

Figure 4 shows the plan of an ocean magnetic survey known as Project Magnet already un-

derway by the U. S. Navy's Hydrographic Office. This great and important project is established on a permanent basis, recognizing therefore the need for continuous information respecting the changing geomagnetic main field for scientific researches and the numerous practical applications of geomagnetic information. Magnetic surveys over land are also included in special instances. In general track spacings of about 200 miles are sought and navigation to within a few miles or better. Measurements of total magnetic intensity, declination, and inclination are made, with navigation by visual, radar, loran, celestial, and other available means. Under good survey conditions the total magnetic intensity is measured to about ± 15 gammas (one gamma = 10^{-4} cgs unit), and angular directions to about $\pm 0.1^\circ$ of arc. It is stated that the reduced data will be kept at the U. S. Hydrographic Office, with a copy forwarded to a U. S. magnetic data repository such as the U. S. Coast and Geodetic Survey.

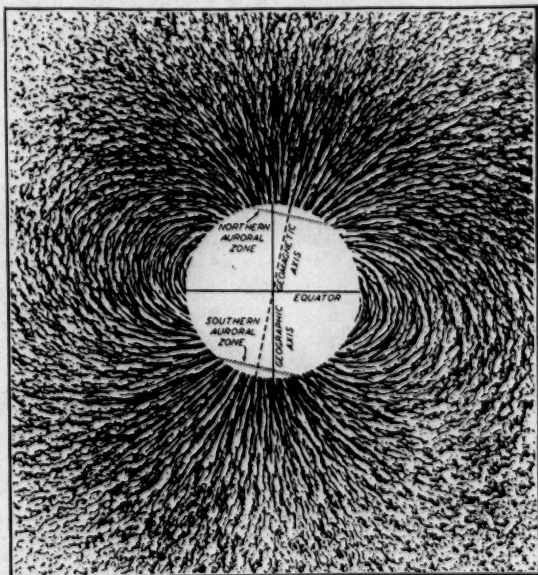


FIG. 5—The magnetic field about the Earth

According to latest information two planes, with reserve magnetometers available, are undertaking this survey.

It is also reported that other nations will undertake similar surveys, over local waters or over land.

World magnetic charts of the Earth's main field and its secular change—The geomagnetic field at the Earth's surface and in the Earth's atmosphere closely resembles that of a short bar magnet imagined near the Earth's center, with its north seeking pole directed towards the Antarctic continent. This is illustrated in Figure 5. Actually, the axis of a uniformly magnetized sphere most closely approximating the Earth's main field is inclined about 11.5° to the Earth's axis of rotation. The pole of this axis is near Thule, in northern Greenland. Because of irregularities in the internal distribution of sources of the geomagnetic main field and their changes with time the actual pole continuously changes and is at present in northern Canada.

World magnetic charts are issued every ten years in most field components, and every five years or so in declination, because of its use in navigation by compass. Charts were compiled and issued recently by the British Admiralty, the U. S. Hydrographic Office, and the USSR, for epoch 1955.0. The reductions of data were made independently, though data obtained or collected were interchanged, published, or inferred from earlier charts such as those issued for 1945. In a sense, therefore, the issuing of three sets of charts has afforded a partial means of international exchange of data, although the British and American charts are now compared and disagreements resolved prior to publication.

Figures 6, 7, and 8 illustrate versions of the world charts for 1955 issued by the U. S. Navy Hydrographic Office. In Figure 9, the secular change in vertical magnetic intensity from 1889 to 1955 is indicated. The substantial changes in so short a period of time illustrate the need for a suitable continuous and consistent effort in world magnetic surveys over all parts of the Earth. Figure 10 indicates similar results for horizontal intensity for epoch 1912.5 based on later surveys only. Figure 11 indicates the density of measurements previously available for use in constructing charts. The data are

incomplete, but give a good indication of the density of measurements.

Analyses of the main field—It was shown by Gauss that the geomagnetic field could advantageously be analyzed using a technique of spherical harmonic analysis. Among the more important advantages are the provision of charts such as those of Figures 6, 7, and 8 drawn so that they are mutually consistent. In addition charts of the main field can be computed for regions of space. For most purposes it suffices to regard the earth as spherical since the flattening at the poles is slight [Chapman and Bartels, 1940].

If the geomagnetic field over the surface of a spherical earth is measured it can be regarded as having a magnetic potential V expressible in spherical harmonics as

$$V = a \sum_{n=1}^{\infty} \{ (r/a)^n T_n^* + (a/r)^{n+1} T_n^* \} = V^* + V^i \quad (1)$$

where

$$T_n^* = \sum_{m=0}^n (g_n^m \cos m\lambda + h_n^m \sin m\lambda) P_n^m(\cos \theta)$$

where the origin of spherical coordinates (r, θ, λ) is taken at the Earth's center. Here r is the distance from the Earth's center, θ the geographic colatitude, and λ the longitude east of Greenwich, and a the Earth's radius. Also, g_n^m and h_n^m are constants to be determined from the charted data, and the affixes e and i refer to the contributions from sources above and internal to the Earth's surface, respectively. The function $P_n^m(\cos \theta)$ is the associated partially normalized Legendre function of Schmidt.

Recent analyses have not indicated that V^* exists with certainty. Typical results are shown in Tables 1, 2, 3, and 4. From the tables it appears that a summation including terms to $m = n = 6$ does not give results differing much from that for $m = n = 15$, in the case of charts for 1945. It is also clear that the calculated external part of the field estimated uniquely from each analysis separately is small. According to Fanslau and Kautzleben [1958], it did not help to use terms in $m = n > 6$, as they find that the higher-degree terms reflect mainly

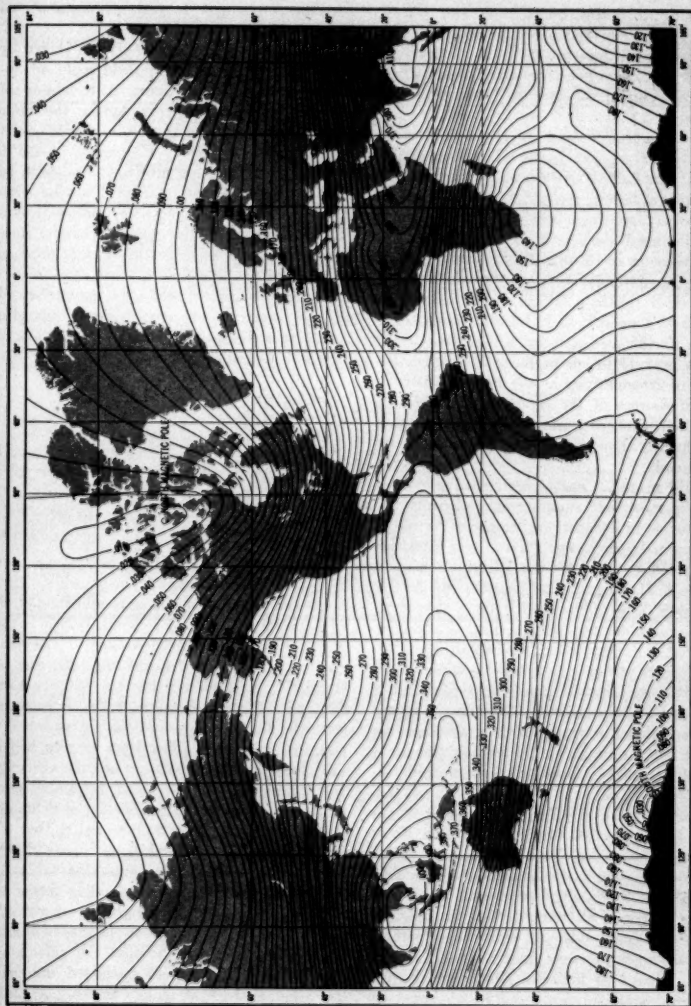


FIG. 7.—World map of magnetic horizontal intensity H ; lines connect points of equal values of horizontal intensity, numerical values in cgs unit, 1955; courtesy, U. S. Hydrographic Office and Encyclopedia Britannica

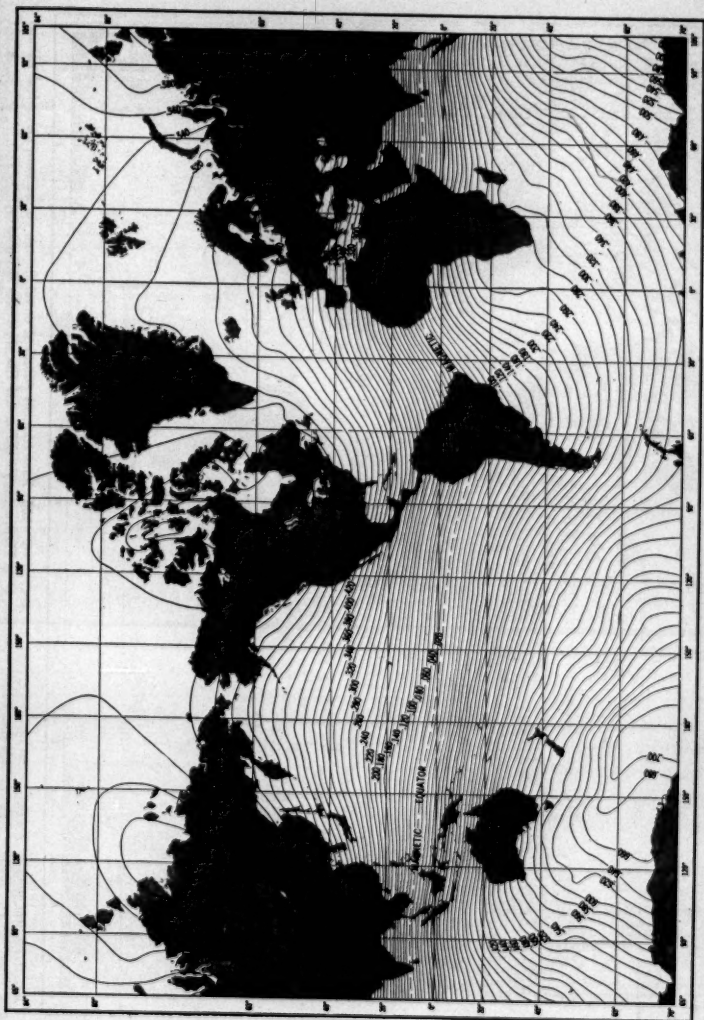


FIG. 8.—World map of magnetic vertical intensity Z ; lines connect points of equal values of vertical intensity, numerical values in cgs unit, 1955; courtesy, U. S. Hydrographic Office and Encyclopedia Britannica

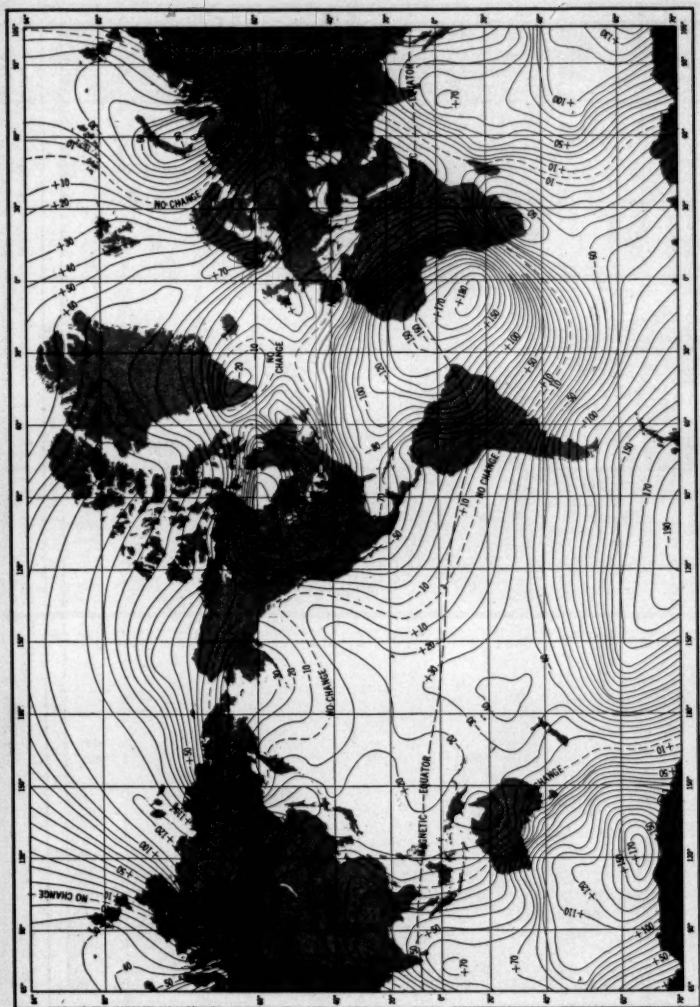


FIG. 9.—World map of secular variation in vertical intensity, 1889-1955; lines connect points of equal change per annum, numerical values in cgs unit times 10^{-4} ; courtesy, U. S. Hydrographic Office and Encyclopedia Britannica

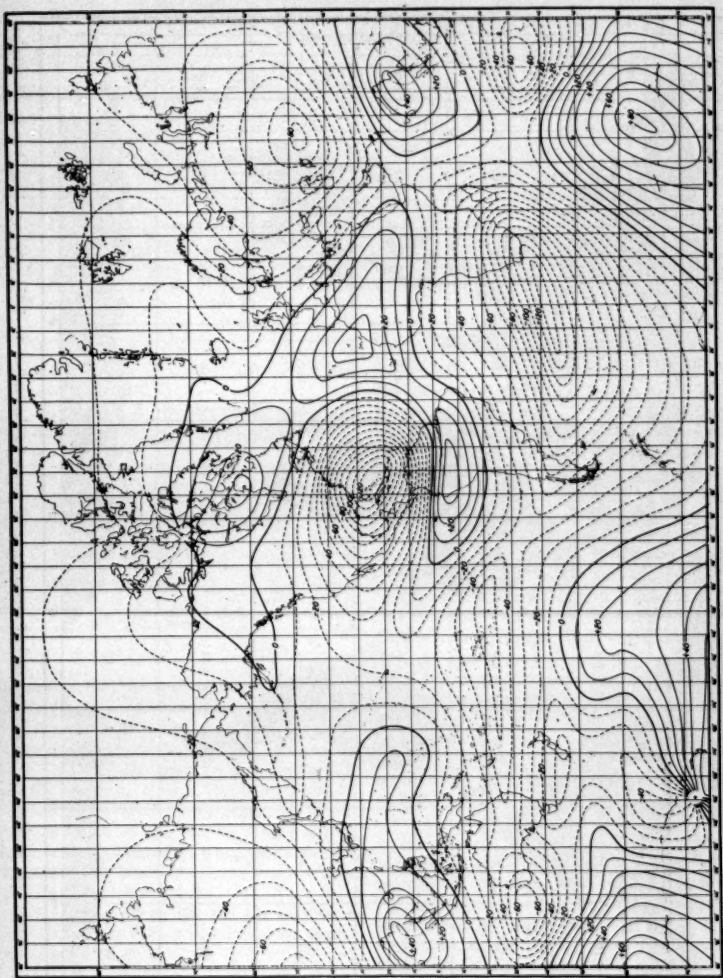


FIG. 10—Isoporic chart for horizontal intensity (lines of equal annual change in gammas per year), epoch 1912.5; courtesy, the Carnegie Institution of Washington

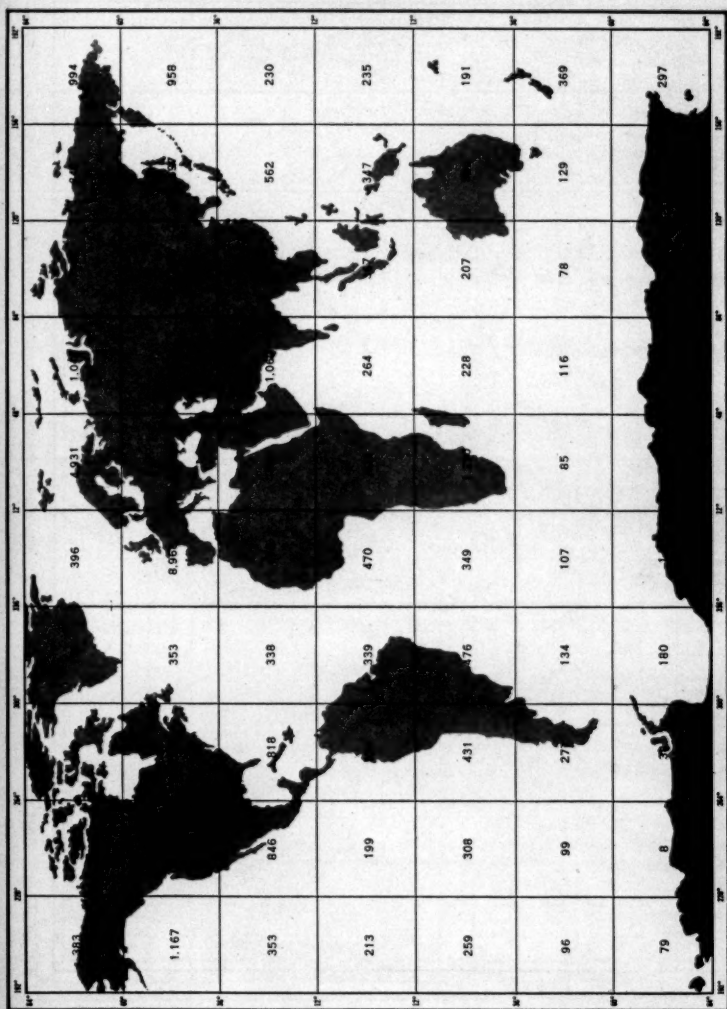


FIG. 11—World map showing approximate number of observations of magnetic declination to 1955; courtesy Encyclopedia Britannica.

TABLE 1—Gauss coefficients of the earth's potential expressed in units of 10^{-4} cgs
[Vestine and others, 1947]

<i>m</i>	0	1	2	3	4	5	6
<i>n</i>							
1 <i>g</i>	-3057	-211					
1 <i>h</i>		+581					
2 <i>g</i>	-127	+296	+164				
2 <i>h</i>		-166	+54				
3 <i>g</i>	+115	-173	+121	+88			
3 <i>h</i>		-52	+19	+3			
4 <i>g</i>	+92	+78	+58	-38	+31		
		+14	-28	-8	-13		
5 <i>g</i>	-24	+28	+20	-6	-15	-7	
5 <i>h</i>		+3	+7	-2	-14	+8	
6 <i>g</i>	+6	+11	-3	-26	-3	-13	-11
6 <i>h</i>		-7	+15	-2	0	-1	-4

the inaccuracies in the data, in the case of the world charts for 1945.

If *X*, *Y*, and *Z* are the north, east, and vertical components of the field, dropping affixes from

$$V = a \sum (a/r)^{n+1} (g_n^m \cos m\lambda + h_n^m \sin m\lambda) P_n^m(\cos \theta) \quad (2)$$

and

$$\left. \begin{aligned} X &= \partial V / r \partial \theta, \\ Y &= -(1/r \sin \theta) \partial V / \partial \phi \\ Z &= \partial V / \partial r \end{aligned} \right\} \quad (3)$$

and since g_n^m , h_n^m are inferred from the observed values of the space derivatives *X*, *Y*, and *Z*, it is clear that the Earth's main magnetic field, of internal origin, can be computed in terms of *X*, *Y*, and *Z* at all points (*r*, *θ*, *λ*) using (2) and (3) for *r* ≥ *a*.

Also, a line of force *s* in space may be traced from equations of this line of force such as $dx/ds = (\partial V / \partial x) / \text{grad } V$, etc. where the co-ordinates are transformed to (*x*, *y*, *z*), say, [Block and Herlofson, 1956].

It is also clear from (2) and (3) that since the total intensity *F*, a scalar positive quantity, is given by

$$F^2 = X^2 + Y^2 + Z^2 \quad (4)$$

where *X*, *Y*, and *Z* are given by (2) and (3), a representation giving *F* in space is readily available, as Zmuda [1958] has shown.

Since a finite number of terms of (2) suffices due to convergence of the series for natural reasons, measurement of *F* at a sufficient number of points in space suffices to determine g_n^m , h_n^m also, though the necessary computing is conveniently best left to an electronic computer. Also, the values of *X*, *Y*, and *Z* may be computed for terms up to and including *m* = *n*, the value of *n* being a matter of choice at the discretion of the individual undertaking the analysis, now about one per cent accuracy.

It is also feasible to compute values of *X*, *Y*, and *Z*, and the field lines in space, and over the Earth's surface, using methods based on surface integrals. But this method, though superior for some purposes, does not seem to lend itself conveniently to analyses of values of total magnetic intensity.

It might therefore be surmised that surveys of total magnetic intensity by airborne magnetometer, together with a substantial analysis program is the convenient and natural way to achieve a principal aim of the proposed world survey. It would be instructive to attempt such an analysis, at least for lower degree terms, especially if the values of *F* were measured so high above the Earth that the higher degree terms could be neglected. For this reason, a world magnetic survey by earth satellite may afford certain advantages. This will next be considered.

Magnetic surveys by Earth satellite—Some members of the Committee on World Magnetic Surveys and Magnetic Charts of the International Association on Geomagnetism and Aer-

TABLE 2—Values of g_n^m , h_n^m , to $m = n = 15$, $\text{ref } 5.0$ [Fanslau and Kautlebom, 1958] units of 10^{-4} cgs

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	g	-3066.78	-216.03													
2	g	+577.35	+154.70													
3	g	-127.89	+295.06	+58.11												
4	g	+111.91	-174.54	+124.27	+89.89											
5	g	+91.02	+53.40	+53.56	-38.79	-12.85										
6	g	-26.92	+13.03	-23.21	-9.52	-16.41	-7.88									
7	g	+36.31	+20.83	+20.83	+0.70	-13.49	+12.58	-11.44								
8	g	+3.60	+8.36	+8.36	+0.02	-0.02	+3.50	-2.35	+2.03							
9	g	+4.35	-10.57	-3.15	-26.77	-0.25	+1.07	-2.35	+2.03	+1.01						
10	g	+8.99	-7.44	+5.60	-2.05	+4.33	-2.05	+2.03	+1.01	+1.01	+1.01					
11	g	+0.28	+3.46	-7.44	+2.33	+2.70	+1.31	-1.62	+1.02	-1.04	-1.04	-1.04				
12	g	+2.41	-0.50	+5.62	-1.04	-0.42	+0.99	+1.03	+1.50	-0.37	-0.37	-0.37	-0.37			
13	g	+1.34	+1.12	-5.13	-1.40	+0.62	+0.78	+0.86	-0.47	-0.71	-0.38	+0.06	+0.72	+3.15		
14	g	+0.38	-1.73	+2.50	+1.18	-0.53	+0.43	-0.01	+0.11	+0.12	-0.04	-0.04	-0.04	-0.32	-0.32	
15	g	+0.31	+1.06	-1.39	+2.45	+0.93	-0.10	+0.01	-0.16	-0.98	+0.43	-0.54	-0.79	-0.79	-0.79	
16	g	+0.13	-2.39	+2.05	+0.23	+0.22	-0.81	-0.33	-0.07	+0.18	+0.38	-0.04	-0.37	-0.48	-0.48	
17	g	+0.04	-0.56	+0.44	-0.61	+0.32	-0.37	+0.77	+0.36	+0.25	-0.04	+0.54	+0.54	+0.54	+0.54	
18	g	+1.41	-0.64	-0.50	+0.48	+0.47	+0.40	+0.24	+0.21	+0.21	+0.45	-0.37	-0.15	-1.03	+0.51	-0.27
19	g	+0.67	+0.00	-0.03	+0.56	+0.61	+0.31	+0.03	-0.10	-0.12	+0.45	+0.34	-0.10	+0.33	-0.80	-0.85
20	g	+0.24	+0.35	+1.26	-0.03	+0.47	+0.43	+0.07	-0.20	-0.12	-0.39	-0.46	-0.46	-0.03	+0.02	+0.08
21	g	+1.96	-0.60	-0.49	+1.26	-0.47	-0.34	+0.78	+0.20	+0.14	-0.73	+0.05	-0.29	+0.04	+0.38	+0.95
22	g	+0.80	+0.48	-1.16	-0.36	+0.38	-0.20	+0.70	+0.08	-0.48	-0.30	-0.80	-0.67	-0.50	+0.16	+0.16

TABLE 3—Spherical-harmonic coefficients of the average annual secular variation expressed in units of 10^{-3} cgs/year

Source	Epoch	g_1^0	g_1^1	h_1^1	g_2^0	g_2^1	h_2^1	g_2^2	h_2^2
Dyson-Schmidt	1922-1885	+20	-1	-1	-10	+6	-14	+21	-18
Bartels	1920-1902	+42	-9	+12	-7	+8	-25	+13	-8
Carlheim-Gyllensköld	1920-1902	0	+13	+4	0	-4	-12	+13	-17
Vestine and Lange	1912.5	+25	+1	-7	-7	-1	-9	+24	-17
	1922.5	+28	+4	-7	-10	+1	-14	+17	-17
	1932.5	+23	+1	-5	-14	+1	-18	+10	-14
	1942.5	+9	+2	+1	-18	0	-20	+2	-14

TABLE 4—Values of $C_n^m = [(g_n^m)^2 + (h_n^m)^2]^{1/2}$ for field of origin external and internal to the Earth (after Fauselau and Kautzleben) units of 10^{-4} cgs

Source	Field	m n	0 1	0 2	1 1	1 2	2 2
Fauselau-Kautzleben	Combined		3067	128	616	340	165
	Inner		3063	123	620	341	169
	Outer		4	5	8	3	9
Vestine-Lange	Combined		3057	127	618	339	173
	Inner		3057	122	620	340	172
	Outer		0	5	12	4	4
Chakrabarty	Combined		3056	127	595	343	156
	Inner		3044	123	613	340	166
	Outer		12	4	20	5	11

onomy, at the time of the CSAGI meeting in Moscow in July 1958 considered the question of the proposed world magnetic survey. One of the suggestions was that magnetic measurements by Earth satellite be considered as a contribution to the survey. In particular, measurements already being made by Sputnik III were mentioned. The question has also been discussed by many others concerned with rocket and satellite programs. The general considerations have perhaps been most clearly visualized and stated by Chapman [1959] recently in his von Humbolt lecture, where he notes that the low-degree harmonics of (1) are perhaps best determined from the smoother geomagnetic field at satellite level, on selected days if necessary.

It therefore appears that the proposed world survey should be conducted using four main approaches simultaneously: (1) by satellite-borne magnetometer, (2) airborne magnetometer, (3) ocean measurements by non-magnetic ship, and (4) by land magnetic surveys.

In general, the field should be specified both

in magnitude and direction, especially at satellite levels in space where the main field might be small [Pushkov and Dolginev, 1957]. But even if the directions are noted imperfectly, provided the total intensity is measured with suitable accuracy, it is clear from the foregoing analyses that great and unique advantages to the world magnetic survey will result. Moreover, a complete survey by Earth satellite using suitable magnetic instruments can be made in a very short time so that problems of secular change will not seriously arise, though there may be other transient effects; for example, those caused by polar disturbances which will affect results, and therefore require separate land and rocket measurements as controls. It is also apparent that polar orbits will be needed to afford full coverage.

The problem of magnetic secular change—In the past, effort in magnetic survey coverage has been more complete in some decades than in others. Since the cartographer's construction of charts for a given year is necessarily based upon observations made at different times and

in different places, it is imperative to have estimates of geomagnetic secular change. The world-wide features and pattern of secular change is also of great interest as a geophysical phenomenon in its own right, since it is an indication of events arising from the otherwise inaccessible deep interior of the Earth. This means (1) that satellite surveys should be repeated from time to time, (2) airborne magnetometer surveys over the oceans must be repetitive, (3) surveys by non-magnetic ship must be repetitive in time and locale, (4) land magnetic surveys are necessarily also repetitive, and (5) magnetic observatories which provide secular change at nearly 200 points over the Earth will face fresh and insistent enhanced demands for nearly current secular change information. The addition of several new observatories in regions now remote from existing observatories will be necessary. It would also be advantageous to devise and place a few observatories in remote areas, to measure magnetic variations with time on the ocean floor.

Reduction of results—It is probably well to remark that the reduction of results offers no special difficulty. Existing methods are adequate, and no fundamental difficulty should arise. The mode of reduction will depend upon the agency concerned, and the needs anticipated. Some cartographers will require a very carefully made analysis. In other instances less demanding needs may require coarser evaluation. It seems likely that one or two organizations should suffice to provide most of the world's needs, however. A permanent service of some kind is imperative, in order to promote international cooperation and exchange, and dissemination and publication of data, in reasonable accord with the desires of international associations and unions.

Technical recommendations of existing committees—(A) The world magnetic survey was established at the international CSAGI meeting of July 1958 as a deferred item of the IGY program.

The Committee on Magnetic Surveys and Charts of the International Association of Geomagnetism and Aeronomy, International Union of Geodesy and Geophysics, has submitted a number of recommendations of technical character, which will be elaborated upon and perfected at the forthcoming IAGA meeting in

Helsinki, July 1960, where a half-day symposium on the subject is scheduled. Speakers from various countries have agreed to participate. Among the questions to be discussed are questions of surveys by Earth satellite, by aircraft, non-magnetic ships, and land parties. The scale and contour intervals of charts desired will define the scope and accuracy of the survey. The geomagnetic field at several Earth radii may undergo substantial transient changes measurable in the survey.

(B) The CIG (Comité International de Géophysique, the successor of the CSAGI) notes need for supporting work with rockets, upper-air researches of various kinds, and ground observations. It is clear that a magnetometer carried by Earth satellite will be likely to pass through electric currents which flow on a transient basis in auroral regions. From ground observations the likelihood of this can be ascertained, as well as from the appearance of magnetic changes occurring more abruptly in time, during satellite observations. Since the motion of satellites is mainly horizontal, some vertical rocket flights would also be useful [Pushkov and Dolginev, 1957]. A careful study of these potential needs is necessary.

Future studies—At the international level a two-day study group is being organized to draft some technical recommendations on the World Magnetic Survey. Participation by active workers is desired. A meeting in Copenhagen during the aeronomy symposium is expected. The group is designed to assist and report to the IAGA Committee on World Magnetic Surveys and Magnetic Charts in Helsinki in August 1960 who will in turn submit final technical recommendations.

Readers will also be interested in the following resolution, adopted by the CIG, when this new body met in the Hague in November 1959.

"In the light of the provision that: 'The CIG shall consider needs in the geophysical and related sciences requiring interdisciplinary activity,' the CIG invites the advice of the discipline members, the sponsoring Unions, and adhering academies. In this connection, special notice is taken of the World Magnetic Survey, initially proposed during the IGY by Professor Sydney Chapman, and scheduled for a quiet interval in the solar cycle.

"The Committee affirms the need and merit

for this Survey and believes that adjoint programmes in the field of upper atmosphere research should be considered for conduct during this same period."

Other recommendations may arise during the symposium on the world magnetic survey at the Helsinki meeting. James Heppner of USA will discuss magnetic surveys by Earth satellite. N. V. Pushkov of the USSR will report on the survey, and discuss Sputnik results. Seron of Canada will report on airborne magnetometer surveys. Nagata of Japan will discuss secular change for ground, air, ocean, and satellite surveys, with the writer serving as Chairman of the Symposium.

This bold and great international project promises high hope of success, in the highest traditions of international scientific cooperation and achievement of the IGY, during the period 1960-65 and on a continuing basis in later years.

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The International Union of Geodesy and Geophysics

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The International Union of Geodesy and Geophysics (IUGG) will hold its XIIth General Assembly in Helsinki, Finland, this summer from July 25 to August 6. The Union normally convenes a General Assembly every three years, the XIth having been held in Toronto, Canada, in September 1957. Many scientists of the United States were able to attend this meeting because of its nearness. All who did so will agree that this kind of gathering offers an unparalleled opportunity to meet with scientific colleagues from almost all parts of the world to discuss problems of common interest.

The opportunity to attend a General Assembly, however, does not always mean that an individual is able to visualize the nature and methods of operation of the Union and its constituent parts. The scope of interests covered by the IUGG and its seven constituent Associations, as reflected in the proceedings of a General Assembly, is broad; numerous administrative matters are dealt with; the number of attending scientists is large (1165 were officially registered at the Toronto General Assembly).

The purpose of this note therefore is to provide a summary account of the IUGG, including its background, objectives, structure, and method of operation, as preparation for clearer understanding of the Union's affairs to be conducted at Helsinki this summer.

Science is international, a phrase both trite and true. From the initial emergence of science as a recognized area of learning, scientists in all its varied disciplines have traditionally communicated across national boundaries, except during those periods when world events have precluded such interchanges. Even during armed conflicts there have been historical instances where nations have given special dispensations to their scientists to cooperate with those of enemy countries in fields of basic research.

If one adds to the obvious advantage of international collaboration the need for wide-area coverage required when dealing with geo-

detic and geophysical subjects, it is not surprising that several of the earliest international organizations dealt with these disciplines. The International Geodetic Association, and the International Meteorological Organization, which included a Commission of Terrestrial Magnetism and Atmospheric Electricity, were forerunners of the International Union of Geodesy and Geophysics.

The Union and its Associations were founded in 1919. At that time it became a member of the International Research Council which had also been formed in 1919. When the International Council of Scientific Unions (ICSU) replaced the International Research Council in 1931, the IUGG became one of its scientific members.

The seven international Associations of the IUGG are:

1. Geodesy
2. Seismology and Physics of the Earth's Interior
3. Meteorology and Atmospheric Physics
4. Geomagnetism and Aeronomy
5. Physical Oceanography
6. Volcanology
7. Scientific Hydrology

Although constituent parts of the Union, the Associations operate more or less autonomously. Their respective statutes and by-laws are, however, generally consistent with those of the Union, and they receive their financial support through the Union. Such matters as organizational structure and publication policy are, on the other hand, the prerogatives of individual associations. Thus, for example, the Association of Geodesy is divided into a number of sections and permanent commissions, while several other Associations tie their activities to a series of commissions and committees, some relatively permanent, and others appointed at the time of each General Assembly.

Returning to the Union as a whole, it is ap-

appropriate at this point to quote that portion of the Statutes that defines the objects of the Union. They are:

(a) To promote the study of all problems relating to the figure of the earth and physics of the earth, oceans and atmosphere.

(b) To initiate, facilitate and coordinate research into, and investigation of those problems of geodesy and geophysics which require international cooperation or which are of international interest.

(c) To provide, on an international basis, for discussion and publication of the results of the researches indicated in paragraph (b) above.

(d) To promote coordination of scientific activities of the adhering countries in the disciplines of interest to the Union.

(e) To assist with scientific advice the study of practical problems of a geodetic or geophysical character when such problems present an international aspect or when they require an international cooperation of technicians and facilities.

(f) To sponsor and coordinate the scientific activities of a number of Permanent Services whose object is to collect, analyse and publish geodetic or geophysical data.

In carrying out its functions, the Union depends on a series of internal structures, beginning at the top with the General Assembly and progressing through the Council, Executive Committee, the Bureau, and special or standing committees.

As stated in its statutes, "The authority of the Union in matters exclusively scientific is vested in the adhering countries and exercised collectively through their Delegates meeting in General Assembly." This statute goes on to state that "for all other matters, the authority of the Union is vested in the principal Delegates nominated by the adhering member countries meeting together in the Council of the Union."

In addition to being the final authority of the Union on all purely scientific matters, the General Assembly also elects the President, the two Vice Presidents, and the General Secretary of the Union.

The Council of the Union consists of the Bureau of the Union (hereinafter defined) and the principal delegates of the adhering coun-

tries. In addition to meeting at the time of a General Assembly, the Council may meet during the intervening period as required. It decides upon the admission of new member countries; elects the Finance Committee and the three members at large to the Bureau; receives reports from the General Secretary and considers for ratification decisions or actions of the Executive Committee and the Bureau; considers Finance Committee recommendations and adopts the final Union budget; determines the amount of unit subscription for the ensuing period (this unit can be changed *only* if the contemplated change is circulated to member organization at least three months in advance); reviews from time to time categories of membership of adhering countries; examines questions of general policy or Union administration and appoints such committees as may be deemed necessary in this connection; considers proposals for changes in the statutes and by-laws.

The Executive Committee represents the scientific interests of the Union and consists, in addition to the members of the Bureau, of the retiring president of the Union and the presidents of the seven international Associations. The Executive Committee meets not only at General Assemblies but between these as required. Any vacancy that occurs between General Assemblies among the members of the Bureau and of the Finance Committee is filled by the Executive Committee, subject to subsequent approval by the Council. The Executive Committee coordinates the interests of the Associations with administrative bodies of the IUGG, initiating actions required such as arranging meetings between the General Secretary of the Union and the Secretaries of the Associations and making recommendations to the Finance Committee concerning the needs of the several Associations. In addition, the Executive Committee makes recommendations to the Council on general policy of the Union.

The normal business of the Union between General Assemblies is conducted by the Bureau in accordance with decisions made by the General Assembly and the Council. The Bureau consists of the President of the Union, two Vice Presidents, the General Secretary, and three members appointed at large.

To handle matters of finance, the Council of

the Union elects a Finance Committee made up of five members. These are chosen so as to avoid conflict of interest with the affairs of the Union and its Associations. This Committee examines in detail all budget items both projected and actual and recommends to the Council general lines of finance policy by means of which the Union is able to fulfill its scientific responsibilities.

There are at present 54 countries adhering to the IUGG. Adherence is generally through a national academy or similar scientific institution although, where circumstances require it, it can be through an appropriate Government agency. In the case of the United States, the National Academy of Sciences is the adhering body; the American Geophysical Union was created as the U. S. National Committee. Countries pay membership dues on a sliding scale based on their scientific interests and the degree of geophysical activity in which they are engaged. The present average annual income from such dues is approximately \$43,000. To this is added approximately \$16,000 from UNESCO grants for special symposia, publication assistance, and related functions. Thus, the IUGG is one of the largest, if not the largest, constituent Union under ICSU.

An important function of various of the International Scientific Unions under ICSU is the support of a series of organizations called "Permanent Services." Originally their purpose was to provide on an international basis certain continuing services, primarily in the form of data compilations, coordinating functions, and similar activities.

In 1956 the various Permanent Services were brought together by ICSU in a Federation of Permanent Services of Astronomical and Geophysical Sciences (FAGS). At that time their functions were re-defined to include not only the continuous collection and distribution of observations, information, and data in these sciences but responsibility for their analysis and synthesis, including the drawing of conclusions and the publication of results obtained.

The Permanent Services belonging to FAGS are the following, with their parent Union or Unions indicated in parentheses. It will be noted that in several cases a Permanent Service is operated by the IUGG jointly with one or two other Unions.

- (1) International Time Bureau (IAU-IUGG)
- (2) International Latitude Service (IUGG-IAU)
- (3) Permanent Service of Geomagnetic Indices (IUGG)
- (4) International Gravimetric Bureau (IUGG)
- (5) Service of the "International Seismological Summary" (IUGG)
- (6) International Seismological Bureau (IUGG)
- (7) Service of the Ultra-Violet Measurement (IUGG)
- (8) International Atmospheric Ozone Bureau (IUGG)
- (9) Service of the Quarterly Bulletin of Solar Activity (IAU)
- (10) Central Ursigram Service (URSI-IAU-IUGG)

Now a brief word about programs of the Union, and its Associations, their publications and the scientific nature of the General Assemblies. A detailed listing of Union (through the Associations) programs would cover many pages. To some extent, the titles of the various Permanent Services reflect the nature of these programs. Significant is the fact that through the Union and its Associations scientists in many fields from many lands can discuss, in an informal and objective manner, problems of common interest, including steps that should be taken to undertake cooperation and coordination across national boundaries when such actions are justified. Later, if more formal instruments of understanding are required, the necessary scientific and technical factors will have been largely identified and resolved.

A special kind of program in which the Union has participated was the IGY, the IGC-59, and before these, the Second Polar Year (1932-33). Formal Union participation in the IGY and IGC-59 was limited to those Associations which sponsored active IGY advisory panels. On the other hand, most of the individual scientists in various countries that planned and executed the field programs and are now carrying out research on the data are closely associated with IUGG activities and are active in the work of the Union and its Associations.

Publications absorb a considerable percentage of the total budget of the Union and the Indi-

vidual Associations. These include scientific series published by various Associations, special data compilations, Transactions of Union and Association meetings, and a regular series issued by the General Secretary, called the *IUGG Chronicle*. This latter contains diverse useful information on the current scientific and administrative activities of the Union and its constituent Associations, Committees, etc.

The General Secretary of the IUGG has been authorized to prepare a complete listing of Union and Association publications, including the procedures for their procurement.

Finally, word concerning the scientific programs at the General Assemblies. Most of these activities are organized and conducted by the Associations and various special committees. Each Association formulates its program along lines best suited to its functions, projects, and needs. In some cases, the structure of the scientific program is tied to activities of commissions or special committees. In other cases, papers are grouped roughly by subject matter.

In recent years, perhaps as a result of the IGY, far more emphasis has been placed on

joint meetings between various Associations to consider interdisciplinary topics of common interest. The Helsinki Assembly will be no exception. In fact, far more such joint meetings are now scheduled for this General Assembly than at any time in the past. At a meeting of the IUGG Executive Committee held in Paris in September 1959, the Associations worked out a preliminary agenda proposal designed to minimize conflicts in the scheduling of the scientific program, taking into account the large number of joint meetings.

The Helsinki meeting promises to be one of the most comprehensive and stimulating sessions the IUGG has ever held. Certainly the IGY and IGC-59 results now beginning to emerge, and the tremendous increase in interest in geophysics and related sciences that these activities have sparked provide the necessary ingredients for an outstanding program.

Note—See Special Announcements in recent issues of the *Transactions* (especially pages 24 and 25 of this issue) for further word of the Helsinki meeting.—Ed.

The Present Status and the Promise of Weather Modification

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A note of background—Man's changing the weather primarily means doing something about clouds and precipitation. Some first questions to be asked then are: How do clouds form? How do they grow and dissipate? What is the precipitation mechanism and how is it triggered by nature? And what are the natural controls on cloud systems and severe storms? The answers to these questions and many more should be known quite well before man can seriously contemplate wide-scale weather-modification experiments. In fact, the answers to the above questions are almost completely unknown and yet man has been attempting weather modification down through the centuries in his search for economic gains, adventure, knowledge, and power.

The problems associated with weather modification are not easy ones. Naturally occurring precipitation takes a wide variety of forms, such as rain, snow, hail, sleet, and mist, and it falls from clouds that are complex and variable even in their more simple forms. Then too, in a laboratory as large and as active as the atmosphere, there is the problem of making worthwhile observations and conducting meaningful experiments. Fortunately for today's scientists, many new research tools and techniques have been developed recently and are becoming available. We now have a small shelf of instruments with which to collect scientific data on clouds as they form and develop. Modern aircraft, rockets, balloons, and radar can probe the interior of clouds, and with good photography we can plot their form and shape. With the new research tools and opportunities to use them, I believe we can look forward with high expectation to new discoveries in cloud physics. We must keep in mind however, that progress may not always be as rapid as we may have been led to expect, for cloud physics is a relatively new field of science, pursued by only a handful of researchers over the past 10 to 12 years.

The endeavors of man to modify the weather can be traced back through history for some centuries. A communication on the subject by James P. Espy was published 120 years ago in the *National Gazette and Literary Register* of Philadelphia. Espy was a well-known meteorologist of the time and is the author of a classic book entitled *Philosophy of Storms*. In his communication he suggested that large fires could be built to heat up the atmosphere and generate updrafts which in a humid atmosphere would support large billowy cumulus clouds and lead to rainfall. The idea is not a bad one; in fact, it is seriously being worked on today. In extensive field experiments, the French professor and meteorologist Henri Dessens set fire to hundreds of acres of grassland in the French Congo during recent summer seasons, beginning in 1956. He wished to stimulate the development of large cumulus by superheating the air over the plains and causing rapid and violent updrafts. As the clouds grew the professor conducted a series of artificial nucleation experiments and, with special cameras set up for the purpose, cloud developments were kept under visual observation. The project is a continuing one and the encouraging early results have led Dessens to plan in terms of a huge artificial heat experiment in which more than 100 oil-fed burners are arranged in a circle 250 m in diameter.

Shortly after man adapted explosive for warfare purposes, it was remarked "It always rains after a battle." After the Napoleonic wars and again after the Civil War serious proposals were advanced for carrying out rain-making experiments by shooting explosives into clouds. In 1892 Congress appropriated funds for some experimental work which produced inconclusive results after a year of trials. Today we have many popular conceptions that the atomic or H-bombs can be used to blow up a hurricane or produce other profound effects on the weather. However, great as is the power of

these modern devices, they are nonetheless small by comparison with the less concentrated but tremendously more extensive energies of the atmosphere. Rather than using explosives, I believe we must search for more sophisticated approaches.

The high interest today in weather modification dates from November 1946 when Vincent J. Schaefer and Irving Langmuir dropped pellets of dry ice into a cloud layer over western Massachusetts and observed a small amount of snow fall from the cloud a few moments later. Some days prior to this, Schaefer, while working at the *General Electric Research Laboratory* [1952] had fortuitously discovered that dry ice at a temperature of -80°C when moved through cloud droplets in a deep-freeze unit would generate myriads of tiny ice crystals. This was explained by noting that water droplets freeze spontaneously at temperatures of -40°C or colder. A short while later another coworker, Bernard Vonnegut, had the bright idea that good freezing nuclei might be of a substance with the same six-sided crystalline structure as ice itself. He reasoned that if water vapor will freeze on contact with ice, it might also freeze on other crystals that simulate ice. Soon he tested and found that silver iodide crystals would do the job and do it quite efficiently. As a matter of fact, silver iodide can cause ice crystals to form in clouds that are as warm as -5°C . This is about 10° above the temperature where most naturally occurring freezing nuclei are effective; therefore silver iodide, like dry ice, has the potentiality of triggering precipitation which may not otherwise occur.

Information on the discoveries of Langmuir, Schaefer, and Vonnegut spread quickly throughout the world. The sky was full of amateur rainmakers soon to be joined by small groups of professional meteorologists who formed rainmaking companies. Cloud-seeding and evaluation standards were unknown and over-optimistic claims of artificial rainmaking running up to several hundred per cent were made by ambitious operators. Over the succeeding ten years, rainmaking activities reached their peak. Claims of success followed by counter-claims involved rainmakers, quacks, professional meteorologists, the U. S. Weather Bureau, and eventually reached to the floor of the Congress.

The discovery of cloud seeding could not have come at a more suitable time. A drought of major proportions struck much of the United States and deepened steadily in the years following World War II. The water-hungry people invested hundreds of dollars in fees to the rainmakers in the hope of saving their crops and filling their reservoirs. Most of the money was raised by the farmers and farm groups. At the peak of the business in 1952, about 250 million acres of land were under contract to the rainmakers, about 15% of the total land area of the United States. This figure slipped to 140 million acres by 1956 and to under a million acres by 1959, principally because of the general increase in rainfall experienced throughout the country.

While major emphasis was on practical applications, some basic research on weather modification did flourish in certain laboratories throughout the world. As an example, the scientific community was challenged by a new theory advanced by Bowen [1956] suggesting a relationship between rainfall and meteor showers. The Earth in its orbit is known to pass through streams of dust particles which lie in vast elliptical orbits about the Sun. The larger particles burn up upon entering the Earth's atmosphere and become visible as meteors. The smaller particles fall slowly through the atmosphere as dust. Bowen found rainfall peaks occurred approximately 30 days after prominent meteor showers and suggested that they were due to the nucleating effect of meteoritic dust falling into cloud systems in the lower atmosphere. The time difference being accounted for by the rate of fall of the meteor through the atmosphere.

The Advisory Committee on Weather Control—In 1953, Congress, having been urged by the economic potentialities of weather modification, created the Advisory Committee on Weather Control. For four years the Advisory Committee studied and evaluated public and private cloud seeding experiments and encouraged programs aimed at developing both physical and statistical evaluation methods. Although there was no doubt in 1953 that rain and snow had been caused to fall from clouds by cloud seeding, the major question still remained to be answered—whether precipitation could be increased significantly over a given area.

Meteorologists know that any substantial precipitation requires large streams of moist air and active cloud development. With these conditions present, nature normally will produce rain or snow. It is usually the rainmaker's task to increase the amount of precipitation as needed. And this leads directly to the very knotty problem in rainmaking evaluation; which is: How can one separate the rainfall caused by cloud seeding from that which falls naturally? The Advisory Committee on Weather Control found it necessary to compare the rainfall from seeded storms with that from unseeded ones and seeded target areas with unseeded control areas. However, then when the best statistical tools were used, the evaluation methods were beset with difficult problems resulting from the great natural variability of rainfall, from the inadequate measurement of rainfall amounts, and from the fact that none of the rainmakers' projects had proper statistical design. Some will argue that the failure to obtain overwhelming statistical evidence of precipitation increase shows that increases due to cloud seeding are not large. Nonetheless, a five to ten per cent increase is of great economic importance in some regions of the country.

The two-volume Final Report of the *Advisory Committee on Weather Control* [1957] for the first time placed before the American public a body of available facts and a variety of views on the status of the science of cloud physics and the techniques and practices of cloud seeding and weather modification. The statistical procedures employed by the Committee indicated that the seeding of winter-type storm clouds in mountainous areas in western United States produced an average increase in precipitation of 10 to 15% from seeded storms, with heavy odds that this increase was not the result of natural variations in the amount of rainfall. However, in flat-land areas the same statistical procedures did not detect any increase in precipitation that could be attributed to cloud seeding. This is where the official evaluation record stands today.

The Report also stressed the importance of basic research and recommended that the Federal Government give full encouragement and support to the widest possible research as the

surest and most direct way to success in any attempt at modifying the weather.

The National Science Foundation—The weather-modification program of the National Science Foundation dates from July 11, 1958 when Public Law 85-510 was signed by the President. The law directs the Foundation "to initiate and support a program of study, research, and evaluation in the field of weather modification . . ." Public Law 85-510 was a direct outgrowth of the work of the Advisory Committee on Weather Control.

With the receipt of the new legislation the Foundation moved promptly and vigorously into its new area of responsibility and established a new program on weather-modification research and evaluation. Following the usual pattern of Foundation operation, the program is administered principally through grants and contracts with university and other research groups.

The Foundation sought the advice and assistance of outstanding scientists and engineers in framing its program; for weather modification is an area of research involving many talents and disciplines. An Advisory Panel for Weather Modification of distinguished civilian experts was appointed with the following membership: Michael Ference, Jr., Ford Motor Company Scientific Laboratory; Sverre Pettersen, University of Chicago; Vincent J. Schaefer, Rensselaer Polytechnic Institute; Max Woodbury, New York University; and as Chairman, Reuben G. Gustavson, University of Arizona. In an early report to the Director of the Foundation, the Panel stated:

"Placing this important field of research under the aegis of the National Science Foundation has given rise to a new hope and confidence that the instability factors in regard to size and time of support will be removed. This is already bringing young imaginative workers into the field. The rate of advance will to a large measure depend upon the quality of the trained scientists attracted to the problem. If good scientists are to be attracted into the program, the Foundation must be particularly concerned about the financial stability of the program. Generally speaking three-year grants should represent the minimum period for starting new projects."

Recently, the several interested government agencies were invited to appoint representatives to an Interdepartmental Committee formed to keep the government fully advised of the national efforts in the expanding area of meteorology, and to encourage coordination among the related programs. The response from the other government agencies was prompt and gratifying and full cooperation has been assured. The Foundation looks to the Committee to insure a cohesive and effective weather-modification program in which all federal agencies are expected to participate by taking charge of projects suitable to their interests. As early evidence of cooperation, several joint research projects have been established between the Foundation and the Departments of Commerce, Agriculture, and Defense. More joint projects are anticipated as the program moves forward.

The National Science Foundation approach to weather modification is a relatively simple and straightforward one. The program has the objective of studying more intensely than has been attempted before the scientific basis of weather modification through long-term support of competent scientists working in cloud physics and allied fields. The Foundation agrees entirely with Professor Henry G. Houghton [1959] who has written:

"One can be quite confident that the ultimate success of methods for the artificial release and control of precipitation will depend on the acquisition of much more complete basic knowledge of the ways in which nature produces rain and snow. Present attempts at rainmaking are uncomfortably close to shooting in the dark. This is not to say that nothing has been learned from or accomplished by these efforts, but simply that the effective control of any mechanism demands much more complete information than is now available on natural precipitation."

Under the National Science Foundation program a full range of theoretical studies and laboratory and field experimental work will be carried out under the direction of research physicists, chemists, mathematicians, and engineers as well as meteorologists. Hopefully, a wide variety of trained scientists will find challenging problems to tackle in weather modification research and evaluation. Appended to

this article is a summary listing of grants and contracts made by the foundation during the first eighteen months of program operation. The list is illustrative of the broad sweep of the program in its preliminary outline, and the fullness of the program will be realized only as imaginative and extended proposals for research are received from the scientific community.

When the Foundation's program was launched, some special encouragement was given to cloud physics through the support of a series of workshop conferences. The first conference was arranged in February, 1959, by the American Meteorological Society and the Foundation for Instrumentation Education and Research. It brought into sharp focus the need for more sophisticated observation and instrumentation in cloud-physics research. The second conference was held in May 1959 and brought together a number of prominent meteorologists and statisticians to evaluate jointly the fundamental needs for the proper design and conduct of experiments in weather modification. This meeting was organized by the Division of Mathematics of the *National Academy of Sciences* [1959] and has resulted in a thoughtful report setting forth the conclusions and recommendations that followed the more than two days of discussions. The American Geophysical Union managed the third conference held in June, 1959, and in the AGU monograph series is published an excellent report on the meeting in the form of an illustrated book [Weickmann, 1960]. A survey of modern problems and approaches for basic research on the physics of precipitation was the central theme of this conference. Still in the planning stage is a fourth conference which will discuss the contributions of research in surface chemistry to the problems in cloud physics and meteorology.

The Foundation's program also has established direct contact with all known private weather engineers and consulting groups in the country. They have been informed of the new weather-modification research program and each has given assurance of full cooperation in reporting on cloud-seeding operations to the Foundation.

A look to the future—Field research opera-

tions will continue at an increased tempo in the western mountain regions where the Advisory Committee on Weather Control found important rainfall increases. Private industry, universities, and the state and the federal governments, have all joined together in a cloud-seeding project on the West Coast called the Santa Barbara Project. Several other seeding experiments are based in the western mountain states and additional cooperative projects can be expected to take to the field in the near future. Sound meteorological and statistical design will be emphasized. If possible, all field research projects should continue over at least a five- to seven-year period to minimize the problems of annual variability in precipitation. Doubtless the results will more definitely pinpoint the amount and character of precipitation increases cloud seeding may bring to the mountain states of the West. From an economic point of view, it is well to note that a ten per cent increase in the western states snow pack is conservatively estimated to be worth at least one million dollars to the utility companies.

In the flat-land region of Texas, Oklahoma, Nebraska, Missouri, and Iowa, cumulus-type clouds are the principal rain producers during the summer growing season. The problems associated with effective seeding of the cumulus cloud and the evaluation of results in the vast flat-land region are considered more difficult than those associated with West Coast cloud-seeding projects. However, the problems are not insurmountable and one or two projects will be put into the field in 1960, and definitive answers are expected by 1965. The economic payoff of increased rainfall over the farm heartland is all too obvious.

Most of the headlines to date have been given to a display of rainmaking and rainmaking potentials. What of severe-storm suppression? Hail, lightning, tornadoes, hurricanes, are manifestations of dangerous and costly weather conditions. Hail damage to property and crops in the United States adds up to well over \$10 million each year and lightning and tornado damage can run the figure to hundreds of millions. Meteorologists have observed large masses of unstable supercooled cloud regions within the severe storm clouds; therefore, conditions should be good for cloud-seeding effects.

If present theory holds true, proper cloud seeding should result in more gentle rainfall and less severe storm winds, lightning, and hail. There is, however, the troublesome matter of getting the seeding material into the right part of the cloud and in sufficient quantity for efficient seeding. As our techniques improve, storm and hail suppression should be one of the early major advances made in weather modification.

Lastly, let us consider the prospects of large-scale weather and climate control, that is, influencing the weather patterns over entire continents and for a long enough period to modify the seasonal climatic averages. It is conceivable that large-scale weather control could be achieved by influencing small causes in the atmosphere which grow to very large effects, provided such small causes can be isolated or defined closely enough to make influencing them a practical matter. I believe the key to large-scale weather control lies in altering the balance between the amount of solar heat reaching the surface and that reflected back into space. Cloud cover can greatly modify the distribution of heat and perhaps artificial clouds could be maintained over selected areas. To have any important effects, however, any such artificial clouds would have to be maintained over large areas and the cost would doubtless be very great. *Wezler* [1958] has written a thought-provoking article in which he speculates about ways to change the reflectivity of large portions of the Earth's surface. He concludes that current proposals are either impractical or likely to produce cures that are worse than the ailment.

In the fall of 1959, a brief forecast of what may lie ahead in weather modification was presented by H. T. Orville, Captain, USN, Retired, (My Crystal Ball, unpublished) to the Northern California Branch of the American Meteorological Society. For many years he has been intimately associated with weather modification research and evaluation, particularly during the four-year period 1953-1957, when he served as Chairman of the Advisory Committee on Weather Control. His look ahead to the future is as follows:

"The next ten years hold promise of being the most productive in the history of meteorology. Within this time period it is not unrea-

sonable to expect that meteorology will have attained the following objectives in weather modification, primarily because of greatly increased knowledge of atmospheric processes: to clear airports of fog, to alleviate droughts, to increase precipitation substantially, and to eliminate hail and lightning damage. Possibly a successful breakthrough to permit control of hurricane intensity or diversion from tracks which would threaten populous areas. Large scale weather-control measures should be attained within the next 20 years. We will, by this time, have reached the point in international affairs where a world community of friendship and understanding is vital to our survival."

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Appendix—National Science Foundation Research Program on Weather Modification

During the 18-month period July 1958 through December 1959, the National Science Foundation obligated a total of \$1.6 million in launching its new research program on weather modification. The program consists of 19 grants and contracts for laboratory research, field experiments, evaluation studies of theory and practices, and conferences on modern meteorological methods directed toward weather modification.

Field investigations—Nine of the grants and contracts will make extensive use of experiments in the field to study cloud formation and characteristics, and the possible changes in clouds induced by man.

(1) Horace R. Byers and Roscoe R. Braham of the Department of Meteorology, University of Chicago, have received a grant of \$344,700 for a study of "Physical Effects of Silver Iodide Seeding in the Great Plains." Cloud seeding in mountain areas of the Pacific Coast appears to result in measurable increases in precipitation. Over the flat terrain of the Great Plains, however, positive results have not been shown. The University of Chicago project will therefore release silver iodide nuclei from aircraft and investigate the resultant physical changes

in the clouds themselves, rather than attempt to measure statistical departures in precipitation. From this three-year project it is hoped that estimates can be made of the actual physical changes in clouds which result from the seeding, and theories evolved of the process by which these changes occur.

(2) A. Richard Kassander, Louis J. Battan, and James E. McDonald of the Institute of Atmospheric Physics, University of Arizona, have received a grant of \$161,800 for studying "Physics of Clouds and of Cloud Modification." During the summers of 1957 and 1958, under NSF and other grants, cloud-seeding experiments were conducted in investigations of rainfall processes. It was discovered as a result of this work that mean rainfall was approximately 30% higher on seeded than on non-seeded days, and lightning flashes were about nine times more numerous on seeded days. This three-year investigation will continue cloud seeding, with measurements to be made in and around the clouds, in an attempt to improve knowledge of cloud, precipitation and electrification development.

(3) Robert D. Elliott of Aeronautic Research, Inc., Goleta, California, is conducting an

"Investigation of Precipitation Processes and Efficiency of Pacific Coast Storms" under a one-year, \$90,500 grant. Many statistical data on West Coast storms are already available from the Statistical Laboratory of the University of California at Berkeley, and elsewhere. This project is making an intensive effort to obtain and evaluate physical data on West Coast storms. This will then be combined with the statistical data to develop a complete model of a West Coast storm. The data to be measured will include water content, nuclei number, potential gradient, and standard meteorological parameters. Comparisons of natural with artificially nucleated storms will be possible. The investigator has proposed a broader and more comprehensive study that will require another two years' work.

(4) Dwight B. Kline of the United States Weather Bureau, Department of Commerce, is directing an 18-month program which has been granted \$68,900, on "Synoptic Observations and Studies of Freezing Nuclei Anomalies." It has been observed that 30 days after known meteor showers on the Earth, a peak is reached in the number of freezing nuclei in clouds, in widely separated geographical locations. Other apparent coincidences between meteor showers and freezing nuclei have been noted. The U. S. Weather Bureau will conduct a systematic collection of data on freezing nuclei taken at widely scattered places at the same time. It is hoped that definitive information on the effects of meteor dust and particles on cloud nuclei can be obtained from this study.

(5) The Atmospheric Research Group of Pasadena, California has received a one-year, \$57,100 grant to conduct "Field Studies in Cloud Physics Related to Nucleation, Hydro-meteor Development, Electrification, and Cloud Dynamics." Field studies of small, 'simple' clouds will be conducted to investigate the effects of time, temperature, humidity, and drop size of nucleation. Theoretical studies of the initiation of precipitation by ice and water mechanisms will be compared with actual measurements. Cloud seeding is being used as a research tool. Most of the field measurements are carried on in the Flagstaff, Arizona area. A two year extension of the work has been proposed by the investigator.

(6) The National Science Foundation trans-

ferred \$100,000 to the Office of Naval Research to provide joint support for the research of Bernard Vonnegut of Arthur D. Little Inc. on "Cloud Electrification Studies." This work involves studies of the precipitation process and the processes at work in the electrification of thunderstorms. It is a continuing joint project with ONR and the Navy's Bureau of Aeronautics.

(7) Meteorology Research, Inc., has received a \$40,000 contract for two-year "Continued Cloud Physics Studies at Santa Barbara," under the direction of Paul MacCready. For two years this group has operated a radar and made cloud-physics studies, attempting to describe the individual storms encountered in as great detail as possible, determine differences between storms, and formulate hypotheses on the relative seedability of various storms. This work will be continued for the additional two years necessary to maintain required continuity and length of observation to result in maximum benefit.

(8) The U. S. Forest Service Forest Fire Research Laboratory at Missoula, Montana will conduct a study on, "Investigation of Cloud Modification Techniques to the Problem of Lightning-Caused Forest Fires," under the direction of Research Meteorologist Donald Fuquay. A grant in the amount of \$63,900 will support the study for about 2½ years. The two broad objectives of the project are: (a) to gain a more complete understanding of the origin, characteristics, movement, and decay of fire-setting lightning storms in order to promote improved forecasting of their behavior and advance planning for more efficient handling of fire fighting tasks; and, (b) to investigate as fully as possible the potentials of cloud modification techniques to reduce the severity of lightning strike, or the number of fires.

(9) Lyle Andrews of the Nebraska State Teachers College is the investigator of a project on "A Physical Study of a Hail-Suppression Program." He will study the properties of hail samples gathered from areas within and outside of a seeded district to determine if a seeding agent is present in some of the hail and to determine the role that this agent may have had in suppressing hail. Comparisons will be made of the samples on the basis of minimum temperature, structure of hail, undercooling,

and silver ion concentration. The grant, made in the amount of \$11,000, will support the field sample gathering and laboratory work for about 18 months. The cloud seeding activity is supported by farm groups in northeastern Colorado and Northwestern Nebraska.

Laboratory research—Four of the grants and contracts will support experimental work performed principally in the laboratory.

(1) One project will be carried on within the laboratories of the Department of Meteorology of the University of Chicago. Horace R. Byers has received a three-year grant for \$383,700 for "Research in Cloud Physics." A broad program of cloud physics research will be established, dealing with the water resources of clouds and covering nearly all the factors believed to be important in precipitation mechanisms: particles and nuclei, ice nucleation process, growth of ice crystals and water droplets, and others. Experimental laboratory research will make up most of the work, with some field research being undertaken to test laboratory findings.

(2) At the National Bureau of Standards, H. F. McMurdie will pursue his studies of silver iodide for two years or more under a grant for \$40,000. Some of the subject areas he will tackle are: (a) the surface alteration which occurs when crystals of silver iodide are allowed to stand in the open air in a well-lighted laboratory; (b) the rate that micro-crystalline clouding differs on exposed crystal faces; (c) the atomic position and temperature motions to understand the physical properties of silver iodide; and (d) the phase relationship in the system of silver iodide—sodium iodide using differential thermal analysis and high temperature x-ray diffraction. An attempt may also be made to reproduce cloud conditions on a laboratory scale and investigate seeding conditions and results under controlled conditions.

(3) Edward Speyer of the American Machine and Foundry Co. began a study in January 1960 on "Cloud Chamber Measurements of Visible and Infrared Absorptivity of Aerosols." A contract was signed for \$16,800 to conduct a one-year exploratory study. The plans are to investigate laboratory cloud-chamber measurements concerned with absorptivity—the relation between absorptivity and drop size spectrum, water content, mean free-path light

ray, and radar wavelength outside the known absorption bands. Also to be investigated is the effectiveness of various colloidal or water-soluble dyes in increasing the absorptivity. These studies should aid in understanding absorption and what can be done to increase or decrease the absorptivity of various aerosols.

(4) A grant has been made to the State Agricultural College, University of Vermont, in the amount of \$52,700 for a three-year study of molecular association in supersaturated vapors. The investigator, R. T. Howard, will use a unique technique he and his associates have developed to study the problem. He will utilize a diffusion cloud chamber as an absorption cell in an infrared spectrometer. The absorption of the radiation is a function of the degree of supersaturation and using his technique it may be possible to observe the vapor of interest from a state of complete dissociation to a state in which it is highly supersaturated. The studies may provide additional information on molecular changes that take place in the evaporation or condensation processes that occur within the atmosphere.

Statistical evaluation—Three grants have been made for statistical evaluation of cloud seeding experiments.

(1) J. Neyman of the University of California at Berkeley is directing a group in the Statistical Laboratory on "Randomized Cloud Seeding" under a two-year, \$64,900 grant. Cloud-seeding experiments have been conducted for two years in Santa Barbara and Ventura counties, and will be continued. The data available will be subjected to statistical scrutiny independent of any *a priori* hypotheses concerning rainfall distribution, using non-parametric statistical methods with the aid of a high-speed computer. This research will provide a more accurate evaluation of the apparent results of cloud seeding in the California area.

(2) Max A. Woodbury of the Department of Mathematics, New York University, is conducting a two-year "Study of Statistical Evaluation of Weather Modification" under a \$58,800 grant. Purposeful randomization of cloud-seeding experiments has been developed as a methodology in weather-modification investigations. This study proposes to report critically on the current state of these techniques, to develop

new analytical procedures, and to test them as fully as possible.

(3) A one-year evaluation study of hail suppression is underway at the Colorado State University Research Foundation by R. A. Schleusener supported by a grant of \$7,900. Several states are conducting programs designed to suppress hail and reduce crop damage due to hail. These programs vary in size, methods, and scope. This study will endeavor to determine the effectiveness of the hail suppression measures being carried out in north-eastern Colorado during the 1959 hail season. The project is jointly supported by the State of Colorado Water Conservation Board whose funds will support the field data collection, while the NSF grant will support data study and statistical evaluation.

Conferences—Three grants for conference support have been made as part of the program.

(1) The American Geophysical Union has received \$25,000 for a "Conference on Mechanisms of Precipitation Formation."

(2) The National Academy of Sciences—National Research Council has received \$10,000 for a "Conference on the Design and Conduct of Research Programs in Weather Modification," under the direction of S. S. Wilks of the Division of Mathematics.

(3) The Foundation for Instrumentation Education and Research and the American Meteorological Society received \$5,100 for a "Conference on Instrumentation for Cloud and Weather Modification."

Reviews

W. W. MOORHOUSE, *The Study of Rocks in Thin Section*, Harper and Brothers, New York, 514 pp., 18 tables, 226 figures, 18 plates, 2 color plates, 1959, \$8.00.

The primary purpose of this new book is just what the title implies; namely, to provide the student with information requisite for an understanding of rocks as seen in thin section. To this end, the text is subdivided into five major parts:

The first of these (37 pages) deals in a brief but adequate manner with the methods of optical mineralogy. As the author points out, this section is not intended to replace standard texts, but rather to serve as a review, in which capacity it should prove very useful.

The second part (110 pages including determinative tables) includes descriptions of the optical properties of the major rock forming minerals, done in a manner similar to that of other recent textbooks (Wahlstrom, *Petrographic Mineralogy*, 1955; Kerr, *Optical Mineralogy*, 1959). Included in this section are 89 individual photomicrographs of varying quality and 15 tables for mineral identification. The latter are based on a great variety of observable characteristics (crystal form, relief, color, sign, 2V, birefringence, etc.) and although many of the rarer minerals are excluded, the tables should be very useful to the beginning student.

The remaining three parts deal with the petrography of igneous rocks (210 pages), sedimentary rocks (86 pages), and metamorphic rocks (81 pages) respectively. Each subsection within these major groupings (for example, *Andesites, Dacites and Related Rocks*) is discussed with respect to occurrence, mineralogy, texture, alteration, varieties, petrogenesis and economic geology. These sections are illustrated with drawings of thin sections similar to those in Harker's *Metamorphism* or Williams, Turner, and Gilbert's *Petrography*. Unfortunately, many of these drawings are overly diagrammatic. They include, however, most of Wards' 100 *American Rocks* which will be an advantage to those who own this set.

The final chapter deals with the petrography of ores in thin section (17 pages). It is organized in the same manner as the previous chapters.

This book has a number of fine features, as well as one or two rather distinct drawbacks. The organization is excellent. Particularly commendable is the manner in which the innumerable rock varieties are discussed. In his chapter on *Nepheline Syenites*, for example, the author refers to "the impenetrable and tangled growth of rock names that turns this series of rocks into a jungle of nomenclature." It is to his credit that he has added no new vines to the morass, but has ac-

tually performed some land reclamation. This is done by listing only the most important and best-known rock types at the beginning of each chapter, and following with a general description of the group, without reference to specific varieties. The varieties are then merely listed at the end of the chapter.

The section on mineral determination is good, in that it combines adequate descriptive material with numerous graphs of optical properties. In addition, there are a great many 'helpful hints' for mineral identification, not only in this section but throughout the rest of the book.

The poorest part of the book is the section on sedimentary rocks which, to say the least, is very much out of date. The author's unfamiliarity with current literature in this field is indicated by his statement on page 333 that "The study of sedimentary rocks, as compared with igneous rocks, is somewhat hampered by the poverty of terminology." The most recent reference in this section is dated 1951 and although frequent mention is made of the 1949 edition of *Sedimentary Rocks* by Pettijohn, the 2nd edition of this work which was published in 1957 (by Harper and Brothers) is completely ignored. It is also a little disconcerting to see chapter 20 titled *Sandstones and Arkoses*. In short, I think the book would be better off without this section.

All other objections are relatively minor. The photomicrographs would certainly be more useful if they were with the minerals being described instead of all in one section. Such an arrangement would probably be worth the additional printing cost. On the other hand, the color plates, although attractive, could be eliminated without very great a loss. On page 32, the statement is made that 40° is the largest 2V in which the isogyres never leave the field of a Bxa figure. But on the next page (Fig. 28) the isogyres of a Bxa figure are well within the field when the 2V is given as 45°.

In spite of these points, all the sections except that on sedimentary rocks are well done. This book should make a good text for the student who is starting on the optical examination of rock thin sections, as well as providing excellent review material for the more experienced petrologist.

John L. Snyder

LOUIS J. BATTAN, *Radar Meteorology*, Univ. of Chicago Press, 154 pp., 1959, \$6.00.

That branch of meteorological science called radar meteorology, which is now playing such a dramatic role in solving problems of short-period forecasts and warnings of severe local storms, hurricanes, and flash floods, and in meso-scale

research, has long needed a textbook on the subject. The appearance of this book at this time is most opportune. The author is one who has had extensive experience in both the practical and research aspects of the field almost since its inception.

The book comprises 154 pages of text, divided into 15 chapters. The first eight deal with the principles of radar operation, the application of radar theory to meteorology, and those factors in physical meteorology that affect ultimately what one sees on a radar scope. The last seven chapters describe the practical application of radar to such meteorological problems as those that occur in hydrology, cloud-physics research, meso-meteorology, and in airborne operations. There are also useful chapters on echoes from so-called 'clear-air phenomena' and on special instrumental techniques. The book is profusely illustrated and the quality of the radar photographs is generally excellent.

The book is intended to be a "guide to the use of radar for studying and forecasting weather." It represents not only the ideas of the author but also makes reference to nearly all of the worthwhile works that have ensued from research workers in this field for the past 15 years. It is comprehensive in the sense of saying something about almost all facets of radar meteorology but for complete understanding, reference to the original works will be necessary.

The book will be most useful to one well versed in mathematics and one who has a good reference library near at hand. All in all, this is a much-needed and long-awaited book. It represents a very valuable contribution in this new field.

Vaughn D. Rockney

EDWARD A. ACKERMAN AND GEORGE O. G. LÖF,
Technology in American Water Development,
Johns Hopkins Univ. Press, Baltimore, 709
pp. + xv, 27 plates, glossary, folded map
inside back cover, 1959, \$8.30.

This is another in the fine series of books sponsored by Resources for the Future in the interests of improved water-resources management. Part 1 of the text describes the physical and economic environment of water development. After introductory comments, there is a discussion of the occurrence and uses of water in the United States and a summary of the technical problems which challenge water-resource developers.

Part 2 analyzes some technical events and techniques significant to water development. Individual chapters discuss factors which have acted to increase water requirements, techniques capable of decreasing demand, methods of extending the service obtained from a unit of water, improvements promoting scale economies, and techniques extending the range of water recovery. Each subject is discussed by presenting selected cases.

Part 3 considers some of the emerging technology offering potential impact on water use. Atomic energy, use of saline water, weather modification, exploration for and development of groundwater, and water conservation in industry and agriculture are discussed.

Part 4 discusses the administrative problems associated with water developments. After a survey of the existing institutional framework in the United States, the relation of technological advance to administrative organization for planning, for realization of development, and for operation are discussed. The closing chapter previews the emerging technology and administrative organization of the future.

As befits the scope of its topic, the book is a large one. The numerous footnotes, extensive general bibliography, and the many facts and figures quoted in the text testify to the diligent research of the authors. Nevertheless, the authors were forced to the 'case-study' method to present their material. Under each topic, selected subjects are expanded while other pertinent topics are omitted. For example, in presenting the techniques capable of decreasing demand, four cases are discussed—use of saline water in agriculture, drought resistant crops, spray disposal of food processing wastes, and developments in the disposal of wood-pulping wastes. Extending the services afforded by a unit of supply is discussed in terms of multiple-purpose reservoir operation, underground storage of water, water conserving and drought-adapted land use, and water softening practices. It must have been a considerable task to select the material to be included.

The reader who is informed on water problems will no doubt feel that some topics are incompletely discussed and some specialists may feel that important points are omitted. Specialists in various water problems will perhaps question some of the authors' interpretations, especially with regard to the past and future importance of various technologic developments. The informed reader will not, however, question that the authors have made a sincere effort to present the necessary facts with a well-balanced analysis. Even the informed reader will profit from a reading of this book for it presents a broad picture of the water problem, and few readers will be informed on all facets discussed.

The less-informed reader will find a good review of many major topics and should emerge from his reading with a much better understanding of the complexity of the water field. Those who have an interest in water either as technologist, administrator, or just plain U. S. citizen will profit from this book if they are prepared to give the time and thought which an intelligent reading requires.

Ray K. Linsley

A. A. KARTSEV, Z. A. TABASARANSKII, M. I. SUBBOTA, and G. A. MOGILEVSKII, *Geochemical*

Methods of Prospecting and Exploration for Petroleum and Natural Gas, English translation edited by Paul A. Witherspoon and William D. Romey, xxiii + 349 pp. 151 figs.; University of California Press, 1959, \$12.50.

It has long been known that prospecting for oil and gas by geochemical methods, including soil analysis, has been much more widely used in Russia than in this country. However, this book contains the first comprehensive account in English of these techniques, together with the supporting theory. The first chapter consists of a detailed review of the physical and chemical composition and properties of petroleum and natural gas as well as conditions in the containing rocks and surrounding fluids. Special emphasis is placed on the 'metamorphism' of oils. This consists largely of simplification of molecular structure with increasing depth of burial. Oxidation and decomposition by sulphate bearing ground waters also are included by the authors in this category. Too, they call attention to the importance of chemical knowledge of the heavy oil fractions.

The authors classify geochemical prospecting methods as direct and indirect. They place gas detection (including logging) under direct methods, and hydrochemical, soil salt (soil analysis), and microbiological under indirect methods.

Chapter 3 is a thorough treatment of the gases of the Earth's crust, including composition and classification. This discussion is a scientific contribution in its own right and goes far beyond the needs of oil and gas prospecting.

The chapter on gas surveying details the technique of collecting gases from shallow auger holes and analyzing them in the field by absorption methods. The results are mapped, and anomalies studied and classified into several groups. The annular anomaly or 'halo' recognized in the United States is only one of the classifications.

The data given by the authors do not permit the evaluation of the effectiveness of the prospecting method. The maps given are extremely general and small in scale. The authors state, however, that this method does not allow the delineation of the size of the gas pool and that in the search for oil, much supplementary-geological work is required. Best results are obtained in strongly folded regions.

Core gas surveys consist of analysis of absorbed gases obtained from cores of shallow holes three to 20 m deep and also analysis of free gas accumulating in these holes. An interesting refinement is the study of the hydrocarbons absorbed into the lattice of montmorillonite.

The chapter on oil and gas logging will be of considerable interest to American petroleum geologists since the development of this technique apparently has followed parallel and largely independent paths in the two countries. The equipment used is analogous if not very similar. This logging method consists of two ways of detecting oil and gas in the bore of holes drilled by

the rotary method. The first is the detection by the hot-wire-bridge method of gas extracted from the drilling mud. The second is the finding of crude oil in cuttings or drilling mud by irradiation with ultraviolet light causing fluorescence (inaccurately called luminescence in this book). All this is done in a truck-mounted laboratory at the rig. As in the United States, this laboratory also is equipped to keep a drilling time log and to make tests of the properties of the drilling fluid. It is interesting to note that the authors barely mention lithologic examination of the cuttings.

The results of mud logging are plotted on a composite log with both lithologic and electric logs. It is strange that radiation logs are dismissed with the remark that they are not useful in detecting fluid zones. Evidently the development of this type of log has not progressed far in the Soviet Union.

Another curious omission is the lack of any mention of drill-stem testing. In this country, one of the main functions of hydrocarbon mud logging has been to guide drill-stem tests. It is difficult to believe that this very useful testing technique is unknown in Russia.

Prospecting by soil-analysis techniques involving examination of bitumens is discussed at length in two chapters. The authors use the term 'bitumen' to cover a wide range of organic solids soluble in neutral organic liquids, which include many substances not derived from petroleum. Bitumen surveys appear to be similar to soil analysis surveys in the United States, where heavy hydrocarbons in the soil are sought. While little evidence of results is submitted, one gains the impression that this method is not much more successful in finding oil in the USSR than it is in the United States.

There is very detailed discussion of fluorescent (luminescent) methods of analysis for petroleum. Here again, this method seems to have developed largely independently in the two countries. One point that should be mentioned in this discussion is that the authors do not give any data as to the wavelength of the ultraviolet light used in the analyses. This may account for the fact that Table 27 does not present results that agree with the reviewer's experience. Crude oils of about 40 degrees API gravity fluoresce a pale yellow under light of 3600 Å, while heavier oils tend to have an orange tinge under the same conditions. However, the fluorescence of refined oils does tend to be more nearly blue, which agrees more closely with the authors' results. Ultraviolet light of less than 3600 Å is not generally used in the United States, for shorter waves cause confusing mineral fluorescence in well cuttings.

The authors' treatment of hydrochemical methods introduces a means of prospecting which is essentially new to the United States. This consists of analysis of spring and well waters for salts of naphthenic acids, iodides, ammonia, H_2S , and sulfates. The naphthenic soaps, iodides, and

ammonia are claimed to be direct indicators of oil. There are detailed tables showing the indication of oil prospects by various chemical classes of waters. Here again, no information is available as to the success of the method in finding oil.

A method closely related to the above is the measuring of dissolved gas in the water of wells and springs. Essentially, this is the detection of micro-oil seeps and appears to be used as a reconnaissance method.

The soil-salt method is another kind of soil analysis for the detection of Cl, I, Ca, SO₄, SiO₂, Al₂O₃. Radioactivity surveys are treated in this section, since it has been found that radioactive salts are associated with the Cl⁻ ion. An interesting and important point is the authors' strong defense of the hypothesis that soil salt, radioactivity, and many hydrochemical anomalies are indications of geologic structure rather than being direct evidence of oil accumulation.

An experimental method treated in this book is the oxygen-reduction-potential method which relies on the presumption that the presence of hydrocarbons in the soil reduces the redox potential.

Microbiological methods of prospecting are given long and detailed treatment. This chapter is by far the clearest translation of any in the book. Also, it is well organized and has adequate illustrations. Microbiological soil and water surveys apparently are widely used in the USSR in conjunction with other geochemical methods. Microbiological work also is done on cores and well cutting samples with considerable success. The results of these surveys are presented rather fully, with oil-field maps showing the correlation of this method with other geochemical surveys, together

with the location of wells, and structure contours. Apparently this method has been reasonably successful.

The reviewer's evaluation of the geochemical methods presented by the authors is that most of them have some value as reconnaissance methods, perhaps on a par with magnetometer and gravity-meter methods in the field of geophysics. They do not seem to have the resolving power necessary to be economically successful under present conditions in the United States, but may be of some use in foreign reconnaissance. They all seem to require large amounts of semi-technical labor, which is a disadvantage where labor costs are high but may be feasible under the economic system of the USSR.

It is possible that geochemical methods of greater resolving power might be developed in this country if interchanges of substantial information such as is contained in this book could be published in this country. As the authors so aptly remark, there are too many 'advertising articles.' Nevertheless, the authors could have used more non-Russian references in their bibliographies. Out of 335 references, 26 are from English language journals, 11 from other languages (mainly German), and 298 from Russian journals. The reviewer knows that there are a large number of reputable articles on several of the methods in American trade journals.

A handy stratigraphic column is appended to the volume by the editors, but an index would also have been useful. This book is recommended as a solid background for anyone interested in developing direct oil-finding methods and indirect reconnaissance methods.

John M. Hills

List of Recent Books of Interest and Importance to Geophysicists

- BADGLEY, PETER C., *Structural Methods for the Exploration Geologist*, Harper, New York, xv + 280 pp., 1959, \$7.50.
- BOOKER, HENRY G., *An Approach to Electrical Science*, McGraw-Hill, xviii + 826 pp., 1959, \$9.50.
- BOYER, CARL, *The Rainbow*, Yoseloff, New York, 376 pp., 1959, \$10.00.
- CHOW, VEN TE, *Open-Channel Hydraulics*, McGraw-Hill, 704 pp., 1959, \$17.00.
- CHRONIC, JOHN, AND HALKA, *Bibliography of Theses in Geology and Related Sciences*, Pruett Press, Boulder, Colo., 424 pp., 1959, \$15.00.
- CONTINI, RENATO, AND PAUL T. BRYANT (eds.), *Engineering College Research Review, 1969*, Engineering College Research Council of the Amer. Soc. for Engineering Education, Urbana, Ill., xxiv + 445 pp., 1959, \$2.00.
- CORPS OF ENGINEERS, U. S. ARMY, *Snow Hydrology*, OTS, U. S. Dept. of Commerce, Washington, 621 pp., 1959, \$8.00.

- FOURTH MIDWESTERN CONFERENCE ON SOLID MECHANICS, Univ. of Texas, Austin, ix + 530 pp., 1959, \$12.50. (Contains 29 papers given at a conference held in Austin, Texas, September 9-11, 1959.)
- GUTENBERG, BENO, *Physics of the Earth's Interior*, Academic Press, New York, International Geophysics Series, Vol. 1, xii + 240 pp., 1959, \$3.50.
- HESS, SEYMOUR L., *Introduction to Theoretical Meteorology*, Henry Holt and Co., New York, xiv + 362 pp., 1959, \$8.50.
- HUSCHKE, RALPH E. (ed.), *Glossary of Meteorology*, American Meteorological Society, Boston, viii + 638 pp., 1959, \$12.00.
- KARTSEV, A. A., Z. A. TABASARANSKII, M. I. SUBBOTA, AND G. A. MOGILEVSKII, *Geochemical Methods of Prospecting and Exploration for Petroleum and Natural Gas*, Univ. of California Press, Berkeley, xxiii + 349 pp., 1959, \$12.50 (English translation edited by Paul A. Witherpoon and William D. Romey).

- MOORHOUSE, W. W., *The Study of Rocks in Thin Section*, Harper, New York, xvii + 514 pp., 1959, \$3.00.
- NEDECO, NETHERLANDS ENGINEERING CONSULTANTS, *The Hague, River Studies and Recommendations on Improvement of Niger and Benue*, North-Holland Publishing Co., Amsterdam, ix + 1000 pp. + map, 1959.
- SIXTH MIDWESTERN CONFERENCE ON FLUID MECHANICS, Univ. of Texas, Austin, ix + 465 pp., 1959, \$12.50. (Contains 30 papers given at a conference held in Austin, Texas, September 9-11, 1959.)
- SVOBODA, KAROL, *Geofyzikálne Metódy Inžinierskeho A Surovinového Prieskumu*, SVTL, Bratislava, 430 pp., 1958.
- TOCH, ARTHUR, AND G. R. SCHNEIDER (eds.), *Proceedings of the Seventh Hydraulics Conference*, State Univ. of Iowa, Iowa City, Studies in Eng., Bul. 39, 305 pp., 1959, \$3.50. (Contains 15 papers given at a conference held in Iowa City, Iowa, June 16-18, 1958.)
- TWENHOFEL, W. H., *Principles of Sedimentation*, McGraw-Hill, revised second edition, 673 pp., \$10.00.
- U. S. WEATHER BUREAU, *World Weather Records, 1941-1950*, Government Printing Office, Washington, ix + 1361 pp., 1959, \$4.75.
- UNIVERSITY OF SOUTHERN CALIFORNIA (pt. 1) AND U. S. PUBLIC HEALTH SERVICE (pt. 2), *Determination of the Quantity of Oily Substances on Beaches and in Nearshore Waters* (pt. 1) and *Characterization of Coastal Oil Pollution by Submarine Seeps* (pt. 2), State Water Pollution Control Board, Sacramento, Calif., Pub. 21, 61 pp., 1919, \$1.50.
- WHITTEN, CHARLES A., AND KENNETH H. DRUMMOND (eds.), *Contemporary Geodesy*, Geophysical Monograph Number 4, American Geophysical Union, National Academy of Sciences, Publication No. 708, vii + 95 pp., 1959, \$5.50. (Proceedings of a Conference Held at the Harvard College Observatory, Smithsonian Astrophysical Observatory, Cambridge, Massachusetts, December 1-2, 1958.)
- WILSON, J. TUZO, *One Chinese Moon*, Hill and Wang, New York, xiii + 274, 1959, \$4.95.
- WOLFLE, DAZL, *Science and Public Policy*, Univ. of Nebraska Press, 81 pp., 1959, \$1.50.

Contents of Bulletin (Izvestiya), Academy of Sciences, U.S.S.R. Geophysics Series, January-March, 1959

Note—As has been our custom in the last several issues of the *Transactions* (see March 1959, pp. 28-31; June 1959, pp. 124-125; September 1959, pp. 228-229; and December 1959, pp. 357-359), we are listing the Table of Contents of *Izvestiya*, this time of the first three numbers for 1959. These numbers and the others of the 1959 series will be successively available in the English edition during the coming months. Subscription rate for the 1959 series is \$25.00. The twelve numbers each (English edition) of the 1957 (\$25) and the 1958 (\$28) series are still available. Individual numbers are \$5.00 each.

No. 1, January 1959

- Duhamel's principle and asymptotic solutions of the dynamic equations of elasticity theory I, G. A. Skuridin, 8 pp.
- Reflection of elastic waves in a non-homogeneous medium, N. V. Tsapelev, 7 pp.
- Reflection and refraction of seismic waves at a weak interface, B. S. Chekin, 9 pp.
- The dispersion of Rayleigh waves in a two-layer model of the Earth's crust, V. I. Keilis-Borok and I. M. Stesin, 5 pp.
- Wave refraction by aquiferous sands. I, I. S. Berson, Yu. I. Vassil'ev, S. P. Starodubovskaya, 21 pp.
- On the slow motion of a conducting medium in a stationary magnetic field, A. N. Tikhonov and A. G. Sveshnikov, 10 pp.

- Calculation of the final stage in the establishment of an electric field in three layers, O. A. Skugarevskaya, 14 pp.
- The vertical component of the Earth's electric field in Lake Baikal, P. A. Vinogradov, 4 pp.
- An inverse theoretical problem in the electrical prospecting of nonconductive beds emerging at the surface, D. N. Chetaev, 10 pp.
- The properties of the Earth's mantle and the physical nature of the transition layer, V. A. Magnitsky and V. A. Kalinin, 9 pp.
- Radiometrical analysis of rocks according to the spectrum of gamma-radiation, S. V. Iochelson and E. V. Shitov, 10 pp.
- On the dependence of the coefficient of the horizontal macro-exchange in sea upon the averaging period of the current's velocity pulsations, A. N. Geenswei, 3 pp.
- Rocket investigations of short-wave solar radiation, G. S. Ivanov-Kholodny, 14 pp.
- Comparison of various equations of the freezing of supercooled water aerosols, L. G. Kachurin, 9 pp.
- Nonhorizontal visibility at solid cloud cover, K. S. Shifrin and I. N. Minin, 8 pp.
- On the primeval temperature of the Earth, V. S. Safronov, 5 pp.
- Modelling the connection between seismic phenomena and disturbances in the electrical field of rocks due to the piezoelectric effect, M. P. Volarovich and E. I. Parkhomenko, 3 pp.

Possibilities of developing an apparatus for making gravimetrical measurements while in motion, V. V. Fedynsky, 7 pp.

A photo-electric device for recording the energy flux of seismic waves, A. V. Rykov, 6 pp.

High-frequency apparatus for the determination of the surface inclination of the Earth and for recording of earthquake waves, P. F. Shakurov, 3 pp.

Absorption of radiation by moist air. Optical hygrometer, E. I. Bocharov, 8 pp.

Distribution of aurora polaris in the circumpolar region, Ya. I. Feldstein, 2 pp.

CHRONICLE, Theses defended before the Academic Council of the Institute of Physics of the Earth, Academy of Sciences of the USSR, Candidates theses: The magnetic stability of rocks, A. S. Bol'shakov; The distribution of magnetization in rocks for bodies of certain shapes, E. N. Mokhova; The magnetic properties of rocks in which the ferromagnetic component is small, R. S. Taichinov; The endogenous factor in tilting of the Earth's surface, O. I. Yurkevich; The kinematic and dynamic properties of seismic waves refracted at curvilinear boundaries, S. A. Fedotov; Investigation of displacement fields in surface waves for the purpose of determining the dynamic parameters of earthquake foci, T. B. Yanovskaya, 4 pp.

No. 2, February 1959

Wave refraction by aquiferous sands. II, I. S. Berson, Yu. I. Vassil'ev, S. P. Starodubrovskaya, 6 pp.

The determination of the apparent velocities of seismic waves in the Caucasus, E. F. Savarensky, 6 pp.

The separation of geophysical anomalies that are less than the mean square error of the measurements, I. G. Klushin, 8 pp.

A station for intermediate magnetic recording of seismic waves, A. Ya. Melamud, L. L. Khudzin, S. A. Deinega, 17 pp.

Elastic media with imperfect inertia and their models, B. I. Ivakin, 11 pp.

Methods for the study of the elastic properties of rock samples under pressure, O. I. Silaeva, 8 pp.

Dynamics of instantaneous coal and gas outbursts in mines, inferred from seismo-acoustical observations, A. G. Konstantinova, 13 pp.

Comparison of various methods of the harmonic analysis of the tidal deformations of the Earth, B. P. Pertsev, N. N. Pariisky, and M. V. Kramer, 2 pp.

Theory of the two-dimensional problem of magnetic prospecting, V. N. Strakhov, 10 pp.

Determination of periods of free fluctuations of a diurnal and semidiurnal-type in polar seas, F. S. Ratser-Ivanova, 8 pp.

Experiments on influencing cumulus clouds in the Alazanskaya Valley, V. N. Balabanova, N. Sh. Bibilashvili, A. I. Kartsvadze, B. V. Kirukhin, and G. K. Sulakvelidze, 14 pp.

The natural radioactivity of atmospheric precipitates, L. D. Solodikhina, 8 pp.

Thermoconductivity equation for porous media containing saturated vapor, water or ice, G. K. Sulakvelidze, 4 pp.

Small angles of the indicatrix of dispersion, A. E. Mikirov, 8 pp.

Elastic impulses originating in a massif under pressure, S. D. Vinogradov, 5 pp.

Interpolation polynomials applied to the study of the Earth's figure, V. A. Kazinsky, 3 pp.

Bay-like disturbances of the geomagnetic field and accompanying changes in the ionosphere as observed at Murmansk, R. A. Zevakina, 7 pp.

Gravimetric and magneto-metric traverses of the Tagil-Magnitogorsk Ural synclinorium, A. N. Timofeev and O. V. Bellavin, 5 pp.

Contribution to the study of elastic properties of Carpathian rocks, G. I. Petkevich, 4 pp.

Disturbances of the force of gravity by the atmosphere, V. A. Romanyuk, 1 p.

On photoelectrical measurements of luminescence of a nocturnal sky, A. D. Bolyunova and V. M. Morozov, 5 pp.

Nature of a temperature field in a city and phenomenon of anomalous lateral refraction, A. S. Zyusin, 4 pp.

Concerning the Breydo formula for marginal charge of drops, L. G. Makhotkin, 2 pp.

Dependence of refraction index of air upon humidity, K. V. Kazansky, 3 pp.

In the Committee on Physics of the Atmosphere, F. F. Yudalevich, 2 pp.

No. 3, March 1959

Duhamel's principle and the asymptotic solution of the equations of motion of the theory of elasticity. II, G. A. Skuridin, 7 pp.

Elastic waves in layers of finite thickness, Yu. V. Rizinchenko and O. G. Shamina, 17 pp.

High-frequency filtering as a means of eliminating multiple reflections, A. M. Epinat'eva and L. A. Ivanova, 15 pp.

On the determination of the azimuths and emergence angles of a seismic radiation, Ye. F. Savarenskiy, I. V. Ayvazov, 10 pp.

The use of stability parameters for the detailed correlation of profiles, G. N. Petrova and T. A. Ismail-Zade, 16 pp.

The string gravimeter for the measurement of the gravity at sea, A. M. Losinskaya, 12 pp.

Mother-of-Pearl clouds, A. Ya. Driving, 12 pp. On critical precipitation of particles of an aerosol from a viscous flow onto an obstruction, L. M. Levin, 10 pp.

Short-range forecast of field of atmospheric pressure for a three-layered model of the atmosphere, S. V. Nemchinov, 13 pp.

The theory of thermal deformations of the Earth's surface, S. N. Kabuzenko, 5 pp.

The accuracy of interface velocity determination from a system of overtaking transverse travel

- time curves of refracted waves. II, M. M. Radzhabov, 10 pp.
- Paleomagnetic studies of sedimentary rocks of South Eastern Turkmenia, E. G. Gus'kova, 5 pp.
- The fusion temperature of the Earth's mantle and the fusion temperature of iron under high pressures, V. N. Zharkov, 6 pp.
- Long period air waves preceding thunderstorms, I. P. Pasechnik, 5 pp.
- Neutronometry of holes in deposits of manganese and boxites, I. N. Sen'ko-Bulatnyi, 4 pp.
- Local acoustic method of measuring air temperature, M. I. Mordukhovich, 9 pp.
- Book Review (I. A. Kibel', *Introduction to Hydrodynamic Methods of Short-Range Weather Forecasting*), 4 pp.
- CHRONICLE, Fifth Assembly of the Special Committee for the International Geophysical Year, 12 pp.

English Translations of Russian Scientific Journals and Papers

Many more translations of Russian scientific writings are available than is generally realized. In order to indicate what is available, the Office of Technical Services of the U. S. Department of Commerce has begun a semi-monthly publication entitled *Technical Translations* which lists translations, not only from the Russian but from other languages as well, available through various organizations in the United States, Canada, Great Britain, and Australia. Some of these are translations in full; others are abstracts of papers in journals, as indicated below. The following information bears on subjects that are likely to be of special interest to geophysicists.

The initials indicate sources from which translations may be obtained as follows: ATS, Associated Technical Services, Inc., P. O. Box 271, East Orange, New Jersey; CB, Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York; DRB, Defence Research Board, Directorate of Scientific Information, "A" Building, Cartier Square, Ottawa, Ontario, Canada; HIG, Hawaii Institute of Geophysics, University of Hawaii, Honolulu 14, Hawaii; LC, Photoduplication Service, Library of Congress, Washington 25, D. C.; MDF, Morris D. Friedman, Inc., Foreign Technical Translations, 67 Reservoir Street, Needham Heights 94, Massachusetts; OTS, Office of Technical Services, Department of Commerce, Washington 25, D. C.; RR, Royer and Roger, Inc., International Division, Washington, D. C.; SLA, SLA Translation Center, The John Crerar Library, 86 Randolph Street, Chicago 1, Illinois; mi, microfilm; ph, photostat.

Asterisk (*) indicates that this item is also available in AGU's cover-to-cover translation of this publication.

ABSTRACTS OF PAPERS IN JOURNALS AND COMPLETE JOURNALS

- Astronomicheskii Zhurnal (USSR)* (*Astronomical Journal*), 35, no. 2, 169-320, 1958 (abstracts in English); OTS, \$0.70.
- Doklady, Akademiya Nauk SSSR*, 1958 (Proceedings of the Academy of Sciences of the USSR, Geological Sciences Sections, 1958), 120, nos. 1-6, 407-596, 1959; CB, \$40.00; and 121, nos. 1-6, 1959; CB, \$40.00.

- Geokhimiya (Geochemistry)*, no. 2, 3, and 4, 1959 (abstracts in English); OTS, \$0.60 per copy.
- Geokhimiya, Akad. Nauk SSSR (Geochemistry, Academy of Sciences SSSR)*, 122-123, nos. 1-6, 1958; CB, \$25.00 per year.
- Izvestiya, Akademiya Nauk SSSR, Seriya Geograficheskaya (Bulletin, Academy of Sciences, USSR, Geography Series)*, no. 3, 1959 (abstracts in English); OTS, \$0.60.
- Izvestiya, Akademiya Nauk SSSR, Seriya Geologicheskaya (Bulletin, Academy of Sciences, USSR, Geology Series)*, no. 1 and 6, 1959 (abstracts in English); OTS, \$0.50 per copy, \$6.00 per year.
- Izvestiya, Vysshikh Uchebnykh Zavedeniy, Geodeziya i Aerofoto'yemka (Bulletin, Institutes of Higher Learning, Geodesy and Aerial Photography)*, no. 1, 3-164, 1959 (abstracts in English); OTS, \$0.70.
- Meteorologiya i Gidrologiya (Meteorology and Hydrology)*, no. 11, 1958 (abstracts in English); OTS, \$0.70.
- Meteorologiya i Gidrologiya (Meteorology and Hydrology)*, no. 2, 3, 4, 5, 6, and 7, 1959 (abstracts in English); OTS, \$0.70 per copy, \$8.00 per year.
- Geodeziya i Kartografiya (Geodesy and Cartography)*, no. 2, 3, 4, 5, and 6, 1959 (abstracts in English); OTS, \$0.60 per copy, \$7.00 per year.

COMPLETE TRANSLATIONS

- ALEKSEYEV, A. S., Certain laws governing the propagation of waves in an inhomogeneous medium; LC or SLA, mi \$1.80, ph \$1.80 [*Akad. Nauk SSSR, Doklady*, 103, no. 6, 989-992, 1955].
- AL'PERT, YA. L., On a method of studying the ionosphere with the help of an artificial satellite of the Earth; LC or SLA, mi \$2.70, ph \$4.80 [*Uspekhi Fizicheskikh Nauk (USSR)*, 64, no. 1, 3-14, 1958].
- AL'PERT, YA. L., E. F. CHUDSENKO, and B. S. SHAPIRO, Results of research on the outer region of the ionosphere, from observations of the radio signals of Sputnik 1; DRB, T 306 R [*Preliminary Results of Scientific Researches on the First Soviet Artificial Satellites and Rockets, Academy of Sciences, Moscow*, no. 1,

- 40-108, 1958]. (With appendix: Calculation of maximum distance of radiowave propagation in the optical geometric approximation, for a spherical Earth.)
- ANAN'YEV, A. G., Aims of the water economy in connection with the five-year plan; LC or SLA, mi \$2.40, ph \$3.30 [Vestnik Irrigatsii (USSR), 8, no. 2, 6-10, 1930].
- AYGINA, N. P., Conference of higher educational institutions concerning geodetic and photogrammetric instrument construction; LC or SLA, mi \$1.80, ph \$1.80 [Leningrad U. Vestnik (USSR), no. 24, Seriya Geologii i Geografii, no. 4, 118-119, 1958].
- BARAT, G., Quantum starship; OTS, \$0.50 [Yunyy Tekhnik (USSR), 2, no. 12, 46-48, 1957].
- BASKIN, M. L., AND A. A. SEMERCHAN, Growth and coalescence of crystals under the influence of ionizing radiations; DRB, T 290 R [Vestnik Akad. Nauk SSSR, no. 1, 69-70, 1958].
- BELEN'KIY, YA. E., V. N. MIKHAYLOVSKIY, AND A. N. SVENSON, A multichannel telemetering device for coordinated geophysical investigation of wells; ATS, \$7.75 [Geologiya Nefti i Gaza (USSR), 3, no. 1, 52-55, 1959].
- BERENBYM, D. YA., AND G. N. KOCHIKAREV, An unusual hailstorm; LC or SLA, mi \$1.80, ph \$1.80 [Meteorologiya i Gidrologiya (USSR), no. 7, 41, 1958].
- BERZON, I. S., YU. I. VASIL'YEV, AND S. P. STARODUBOVSKAYA, Refracted waves associated with water-bearing sands, I; ATS, \$26.30 [Akad. Nauk SSSR, Izvestiya, Seriya Geofizicheskaya, no. 1, 32-48, 1959].
- BOL'SHAKOVA, L. G., YU. N. GEORGIEVSKI, A. N. OTTO, AND S. F. ROBIONOV, Photoelectrometric study of the night sky luminescence; DRB, T 315 R [Academy of Sciences, Moscow, (Soviet) IGY Information Bulletin, no. 4, 58-59, 1958].
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- ZYABLITSKIY, I. I., The tectonics and oil occurrence of the borderland of the southeastern part of the Russian platform; ATS, \$12.80 [Razvedka i Okhrana Nefti (USSR), 25, no. 2 5-10, 1959].
- ANONYMOUS, Literature on meteorology and hydrology in 1956 (continuation); OTS, \$0.50 [Meteorologiya i Gidrologiya (USSR), no. 6, 59-61, 1957].
- ANONYMOUS, Rockets; LC or SLA, mi \$1.80, ph \$1.80 [Bol'shaya Sovetskaya Entsiklopediya (USSR), 51, 256-259, 1958].
- ANONYMOUS, Soviet artificial Earth satellite; OTS, \$0.50 [Radio, Moscow (USSR), no. 11, 7-10, 1957].
- ANONYMOUS, Space rocket directed to the Moon; about the launching of a space rocket in the direction of the Moon; LC or SLA, mi \$1.80, ph \$1.80 [Sovetskii Patriot (USSR), p. 1, Jan. 4, 1959].
- ANONYMOUS, The motion of an artificial satellite in the noncentral gravitational field of the Earth in the presence of atmospheric resistance; LC or SLA, mi \$2.40, ph \$3.30 [Unidentified Russian article].

COLLECTED PAPERS

- Activities in the Arctic and Antarctic; LC or SLA, mi \$1.80, ph \$1.80 [no. 11, 9 pp., 1959]. (Trans. of unevaluated information selected from foreign-language publications.)
- Activities in the Arctic and Antarctic; LC or SLA, mi \$1.80, ph \$1.80 [no. 12, 8 pp., 1959]. (Trans. of unevaluated information selected from foreign-language publications.)
- Arctic and Antarctic; OTS, \$0.75, [25 pp., 1959]. (Consists of selected translations from Soviet-bloc International Geophysical Year literature.)
- Artificial Earth Satellite Observation; OTS, \$7.5 [Astronomicheskii Zhurnal (USSR), no. 190, 3-5, 11-16, and no. 191, 3-9, 1958].
- Aurora and Airglow; OTS, \$0.50 [10 pp., 1959]. (Consists of selected translations from Soviet-bloc International Geophysical Year literature.)
- Guided Missile Information; LC or SLA, mi \$1.80, ph \$1.80. (Trans. of excerpts from open USSR, Soviet Bloc and other foreign sources, 1959.)
- Meteor Studies; OTS, \$0.50 [19 pp., 1959]. (Consists of selected translations from Soviet-bloc International Geophysical Year literature.)
- Photographic Tracking of Artificial Satellites in the USSR; LC or SLA, mi \$2.40, ph \$3.30 [Soviet open sources, 1957-1959].
- Photographic Tracking of Artificial Satellites in the USSR: Supplement; LC or SLA, mi \$2.40, ph \$3.30 [Mono. Byulleten' Stanits Opticheskogo Nablyudeniya Iksustvennykh Sputnikov, Zemli, Moscow, 1958].
- Radio Communication Centers in the USSR: Listed by Location and Designation; LC or SLA, mi \$2.40, ph \$3.30 [Soviet open sources, 1949-1959]. (Contains information relating to Soviet locational policy and practice as pertains to mainline radio facilities, and indicates the subject areas in which these facilities are to be studied.)
- Results of Observations of Soviet Artificial Earth Satellites No. 1, Sputnik 1958; OTS, \$0.75. (Consists of selected translations from Soviet-bloc International Geophysical Year literature.)
- Scientific Work in Meteorology: Rept., OTS; \$2.50, 116 pp. (Trans. of mono. Soobshcheniye o Nauchnykh Rabotakh po Meteorologii, Moscow, 1957.)
- Soviet Satellite Tracking Effort; LC or SLA, mi \$2.70, ph \$4.80 [Soviet open sources, 1957-1959].
- The Cosmic Rocket: Soviet Literature; OTS, \$1.75 [67 pp., 1959]. (Trans. of five articles selected from Soviet scientific periodicals.)

Notes and Personalia

Notes

• **CORRIGENDUM**—In the paper on the International Geophysical Year by Sydney Chapman, published in the June 1959 issue of the *Transactions*, pages 112-119, a correction is to be noted on page 115. In the right-hand column, third line above *IGY Organization*, it speaks about an eastward subcurrent "with a speed of about 25 miles per hour." This speed should be 25 miles per day.

• **CORRIGENDUM**—In the December 1959 issue of the *Transactions*, page 368, in the news note concerning *Facilities Atop Mount Washington*, the statement is made that Gorham Laboratories of Gorham, Maine, operates the Mount Washington Observatory. Wallace E. Howell, President of Mount Washington Observatory, calls attention to the fact that Mount Washington is, and for more than 25 years has been, a non-profit scientific institution "operated by a Board of Trustees on which Dartmouth College, the University of New Hampshire, and the Appalachian Mountain Club are represented, as well as approximately 2000 members whose annual dues help support the work and publications of the Observatory." He points out that the Observatory has always been interested in making its facilities available to persons and institutions wishing to use the unique situation of Mount Washington for geophysical work. Inquiries concerning this should be sent to Dr. Howell at 35 Moon Hill Road, Lexington 73, Massachusetts.

• **OPPORTUNITIES FOR SCIENTISTS ON ANTARCTIC RESEARCH**—The continuing program of research work in the Antarctic requires a continued recruitment of scientists and others. There has been a lag in applications of competent personnel, but new policies are being instituted which should make such work more attractive. The continued staffing of this program is essential to the maintenance of a balanced program in order to fill gaps in the IGY study. Persons interested in serving on such programs should address their inquiries to Dr. T. O. Jones, National Science Foundation, Washington 25, D. C.

• **FINANCIAL AID TO SUMMER INSTITUTES FOR HIGH SCHOOL AND COLLEGE TEACHERS OF SCIENCE, MATHEMATICS, AND ENGINEERING**—In the summer of 1960 financial aid will be available to about 18,000 high school and college teachers of science, mathematics, and engineering to participate in summer institutes sponsored by the National Science Foundation. Three hundred and seventy-seven institutes will be supported at a cost of more than \$21,000,000. Institutes will be held in all of the 50 states, the District of Columbia, and Puerto Rico. The program for 1960 underscores the fact that previous summer institutes have met an important need and the number has been

growing each year since their founding in 1953. Although inquiries and applications concerning individual participation should be addressed to the directors of the individual institutes, a list of the 379 institutions at which institutes are to be held, with the name of the director, may be secured by writing to the National Science Foundation, Washington 25, D. C.

• **GRANT FOR NEW OCEANOGRAPHIC VESSEL**—The National Science Foundation has made a grant of three million dollars for the design and construction of a new oceanographic vessel. Studies are under way to produce a ship most serviceable for research purposes in modern oceanography.

• **OPPORTUNITIES AT THE NATIONAL RADIO ASTRONOMY OBSERVATORY**—The National Radio Astronomy Observatory, established by the National Science Foundation and operating at Green Bank, West Virginia, under the auspices of Associated Universities, announces that competent scientists who desire to undertake work at the Observatory should apply to the Director, National Radio Astronomy Observatory, P.O. Box 2, Green Bank, West Virginia. The letter should contain a description of the program to be carried out, including a statement of the objects to be investigated and their positions, expected flux densities or antenna temperatures, and receivers to be used, together with information on additional or special equipment needed. It should also include an estimate of time required for the program.

• **GRANTS OF THE FORD FOUNDATION IN SUPPORT OF GEOPHYSICS**—In an effort to increase the number of advanced research scientists in meteorology, oceanography, and plasma physics, the Ford Foundation recently made grants totaling over one million dollars to ten universities for graduate fellowships in these fields to be awarded on both the predoctoral and postdoctoral levels over the next five years. The amounts of the grants range from \$267,000 given to the University of California at La Jolla downward as follows: Princeton University, \$205,000; Massachusetts Institute of Technology, \$150,000; University of California at Los Angeles, \$132,000; California Institute of Technology, \$120,000; University of Colorado, \$117,000; Harvard University, \$100,000; University of Minnesota, \$90,000; University of Chicago, \$70,500; and University of Wisconsin, \$60,000. The largest part is to be used especially for studies in the atmospheric sciences. Applicants for the fellowships should apply to the schools to which the grants have been made. This follows grants totaling over \$19,000,000 made in October to ten universities in support of engineering education. Additional engineering education grants were subsequently given to three other universities.

• **FELLOWSHIPS AND RESEARCH ASSISTANTSHIPS IN**

OCEANOGRAPHY AND METEOROLOGY AT TEXAS A AND M—The Department of Oceanography and Meteorology at Texas A and M College has announced the availability of fellowships and research assistantships to qualified graduates in the sciences and engineering for the academic year 1960-1961. Four fellowships are available with stipends ranging from \$2000 to \$3000 and a number of research assistantships providing \$1800 and upward for a period of twelve months. Application forms can be secured from the Department of Oceanography and Meteorology, Texas A and M College, College Station, Texas.

• **TEACHING FELLOWSHIPS AND ASSISTANTSHIPS AT THE UNIVERSITY OF ALBERTA**—The Physics Department of the University of Alberta is inviting applications from students for graduate study in geophysics covering the broad spectrum of such problems. Support is available for teaching fellowships up to \$3600 for twelve months and teaching assistantships up to \$3200 for twelve months or \$2400 for seven months, and special fellowships carry a stipend of \$2400 for twelve months. Interested persons should send their inquiries and applications as soon as possible to the Physics Department, University of Alberta, Edmonton, Alberta, Canada.

• **TREATY CONCERNING THE ANTARCTIC**—Twelve nations, including the United States, that have been involved in the scientific research work in the Antarctic during IGY and subsequently held an extended conference in the late fall in Washington to define the future of the Antarctic. On December 1 a treaty was signed that provides that Antarctica shall be used for peaceful purposes only and that the international scientific cooperation that characterized the IGY shall continue. Military operations and all forms of nuclear explosions are prohibited in the entire continent. Although the United States has never officially made any territorial claims to areas in the Antarctic even though it has been the chief explorer in the region in the past, the treaty provides that all territorial and sovereignty claims and the positions of all governments concerning the recognition or non-recognition of such claims shall remain in *status quo*. Seven of the signatory countries have made claims, and some of these are overlapping.

• **NINTH NATIONAL CLAY CONFERENCE**—The Ninth National Clay Conference will be held at Purdue University, October 6-8, 1960. Two symposia of invited papers will be held, the topics being "Engineering Aspects of Physico-Chemical Properties of Clays" and "Clay-Organic Complexes." Inquiries should be addressed to J. L. White, Chairman, Ninth National Clay Conference, Department of Agronomy, Purdue University, Lafayette, Indiana. Titles and abstracts of papers should be sent to him by June 1, 1960.

• **WMO WORLD WEATHER MAPS**—As a result of observations during the International Geophysical Year the World Meteorological Organization

plans to prepare world weather maps showing the results of these observations, which form a vast volume of unique meteorological information. It is the intent to prepare world weather maps for each day of the IGY, showing the observations made not only at the Earth's surface but in the upper air. Seventeen countries have expressed willingness to cooperate in this endeavor, and steps are being taken to develop technical specifications to insure uniformity.

• **TENTH PACIFIC SCIENCE CONGRESS**—The Tenth Pacific Science Congress will be held August 21 to September 6, 1961, on the campus of the University of Hawaii in Honolulu. The dates include a three-day, post-session field trip. Among the organizers of the Conference are L. V. Berkner, President of AGU and President of Associated Universities, Inc., for the Section of Geophysical Sciences, and L. D. Bayer, Director of the Experiment Station of the Hawaiian Sugar Planters' Association, for the Section of Agricultural Sciences. Divisions within the Section of Geophysical Sciences are to be organized as follows: C. E. Palmer, Meteorology and Upper Atmosphere; Walter H. Munk, Oceanography; Gordon A. Macdonald, Solid Earth Sciences. Further details can be secured from the Secretariat of the Pacific Science Association, Bishop Museum, Honolulu 17, Hawaii.

• **NEW GEOPHYSICAL OBSERVATORY IN BELGIUM**—The Royal Belgian Meteorological Institute has transferred its magnetic observatory from Uccle, near Brussels, to Dourbes in southeast Belgium. The new observatory has been located at least 15 km from present or potential electric transmission lines. Such a location is difficult to find in Belgium. The new observatory has been equipped for recording the magnetic field, Earth currents, atmospheric electricity, radio atmospherics, atmospheric radioactivity, seismic waves, and variations in the ionosphere. It is described in detail in Publication Series A, No. 7, of the Institute, which contains detailed building plans and other information concerning the design of the new observatory.

• **GRAVITY RESEARCH FOUNDATION AWARDS**—The Gravity Research Foundation announces the offering of five awards for short essays for the purpose of stimulating thought and encouraging work on an understanding of gravity, the essays to be no longer than 1500 words on the possibility of discovering (a) some partial insulator, reflector or absorber of gravity, or (b) some alloy, or other substance, the atoms of which can be agitated or rearranged by gravity to throw off heat, or (c) some other reasonable method of harnessing, controlling, or neutralizing gravity. The essays must be received by the Foundation before April 15, 1960, in two copies on 8½ by 11 paper. The first award is \$1000, ranging down to the fifth which is \$100. A 100-word summary should accompany the essay. These should be forwarded to the

Gravity Research Foundation, New Boston, New Hampshire.

• **UN COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE**—In December 1959 the First Committee of the United Nations (Political and Security) began the discussion of the establishment of a Committee on the Peaceful Uses of Outer Space. Twelve delegations circulated a draft resolution requesting the General Assembly to establish a 24-member Committee on the Peaceful Uses of Outer Space, the task being to review the matter of international cooperation, the study of practical and feasible methods to effectuate programs which could be undertaken under United Nations auspices, and to convene in 1960 or 1961 under UN auspices for an international scientific conference on the subject. The establishment of such a committee parallels the U. S. endeavor under which the National Aeronautics and Space Administration has been established with a supporting board in the National Academy of Sciences, of which latter board Lloyd V. Berkner, President of the American Geophysical Union, is Chairman.

• **PROPOSAL FOR INTERNATIONAL MEETING ON COMMUNICATIONS IN SPACE**—The International Telecommunication Union of the United Nations has recommended the convening of an extraordinary conference before the end of 1963 to make proposals for new services and methods of telecommunications in space to examine the technical progress in the use of telecommunications for space research. It would also decide on the allocation of frequency bands for various categories of space telecommunications and whether there is a continued need for the allocation of some frequencies for space research purposes and to take appropriate action with respect to such allocation. It would also adopt new provisions in the international radio regulations to provide for the identification and control of radio transmissions from space vehicles.

A recent radio communications conference requested its International Radio Consultative Committee to study the question of identification of radio transmission from satellites and other space vehicles, and to investigate the question of provisions for the shutdown of radio transmission from satellites and other space vehicles at appropriate times. In this connection, the conference requested the administrations of the countries launching satellites and other space vehicles to present results of their studies to the International Radio Consultative Committee.

• **GRANT FOR THE STUDIES OF WAVE MOVEMENTS IN THE ATMOSPHERE**—Columbia University has received a grant of \$75,100 from the National Science Foundation for the continuation of studies of invisible wave movements in the atmosphere. Previously scientists at Lamont Geological Observatory of Columbia have detected prominent air waves from Russian nuclear explosions in northern Siberia and American explo-

sions in the Pacific discharged before the ban on nuclear tests became effective in the fall of 1958. The travel has been as far as halfway around the world. This would seem to have an important bearing on probing into the matter of physics of the atmosphere, including the physical properties of the upper atmosphere.

• **CENTENNIAL OF COOPER UNION**—The 100th Anniversary of Cooper Union was celebrated in New York on November 2, 1959, with delegates from about 300 educational institutions and societies in attendance. Among the speakers were Laurence M. Gould, President of Carleton College, who spoke on "Education and Society," and Harold C. Urey of the University of California at La Jolla.

• **NBS JOURNAL OF RESEARCH**—The section of the *Journal of Research of the National Bureau of Standards* dealing with Radio Propagation has announced a new policy whereby it will now include papers by authors outside of the National Bureau of Standards. This section of the *Journal* is edited by James R. Wait (who is also serving as an editor of the *Journal of Geophysical Research* of AGU).

• **DEDICATION OF NEW BUILDING OF THE U. S. GEOLOGICAL SURVEY**—On November 24, 1959, the new, modern quarters to house the topographic mapping facilities of the U. S. Geological Survey for eight Western states was dedicated at Menlo Park, California. The dedication was presided over by Thomas B. Nolan, Director of the Survey, and the dedication was by Fred A. Seaton, Secretary of the Department of the Interior. The cost of the new facility was about \$1,350,000.

• **CURRICULA CHANGES AT COLORADO SCHOOL OF MINES**—An intensive integrated science program is the major change of recent curriculum developments at the Colorado School of Mines, resulting from a two-year study by the faculty, administration, and board of trustees. The major changes are in the departments of mathematics, physics, and chemistry. In mathematics, all students will be required to take at least 17 semester hours during the first two years in much more closely integrated courses than the 20 hours provided in the previous curriculum. In physics, increased emphasis is placed on modern physics. Students are now required to take 13 semester hours of physics in the first two years instead of ten hours as previously. In chemistry, there is a reduction of the first two years from 18 to 16 hours with emphasis on chemical principles including atomic and molecular structure, chemical equilibria, and chemical kinetics. An increased number of semester hours in the humanities is also required.

• **OCEANOGRAPHIC POLLUTION SURVEY OF THE CONTINENTAL SHELF OF SOUTHERN CALIFORNIA**—The California Water Pollution Control Board, noting that marine disposal of sewage is practiced by almost every coastal city in the United States, is conducting a survey of the problem as it relates to the Continental Shelf of Southern California.

The work is being undertaken utilizing the facilities of the Allan Hancock Foundation of the University of Southern California and has already been under way for two years of a five-year program. The progress report covers six sections including marine climate, sediments, physical and chemical characteristics of the water, benthic marine flora, benthic biology, and microbiology. This is Publication No. 20 of the Control Board and may be secured from the Documents Sections of the State Printing Division, Sacramento 14, California, for \$4.00 a copy.

• **HUGE SUBMERGED ISLAND IN THE ARCTIC**—Scientists of Lamont Geological Observatory of Columbia University have charted a huge submerged island in the Arctic that arises over 8000 ft above the ocean bed. The U. S. atomic submarine *Nautilus* reported encountering a huge submerged mountain range in its North Pole crossing in 1958. The Columbia group reported the top of the island to be about 900 ft below the surface of an area of about 14,000 square miles resembling the table lands of mountainous regions of the United States. The Columbia scientists were drifting westward on an ice station when they recorded the island for a distance of about 120 miles. The scientists believe that while the *Nautilus* crossed the southeast corner of the formation, the ice station drifted across its entire width. This was reported on the return from a summer spent on the ice drifting station Alpha II, otherwise known as 'Project Iceskate' which was established in May 1959 at a point 300 miles north of Point Barrow under the sponsorship of the Air Force Cambridge Research Center. Underwater photographs showed an abundance of marine life on the island, while the underwater pictures of the ocean bed showed very little life. The change in depth from 9000 to 900 ft occurred in about $4\frac{1}{2}$ miles of drift.

• **FLYING METEOROLOGICAL STATION OF THE UNIVERSITY OF WISCONSIN**—The University of Wisconsin has a program under way on the study of the lower levels of the atmosphere by means of two small airplanes, especially equipped with meteorological instruments, at elevations ranging to 5000 ft, the regular flight pattern being normally at 2000 ft. Various flight patterns have been established, one a relatively small course around Madison, and other longer trips into various parts of the State. Solar radiation, temperatures, wind directions and velocities, and atmospheric turbulence are among the elements observed in relation to the roughness of the Earth below. Wisconsin is a composite of forests, lakes, and farmland, and the relations of these to atmospheric elements, especially through the changing

seasons and their variation from one area to another, are among the problems being studied. The program is under the direction of Heinz H. Lettau in the Department of Meteorology, which is under the chairmanship of Reid A. Bryson.

• **EAST PACIFIC RISE**—Various Scripps Institution expeditions have extended over an area in the eastern Pacific around Easter Island that establishes further details concerning the East Pacific Rise. The Rise does not seem to be isostatically compensated within the crust as are such volcanic ridges as the Hawaiian Islands and the Aleutian chain. The crust under the Rise seems to be as thin as that under the surrounding ocean areas, namely, about three miles. Under the Rise seismic velocities in the mantle are lower than those found elsewhere in the oceans except under the Mid-Atlantic Ridge, which is a similar oceanic feature. The highest ocean-bottom, heat-flow measurements yet made have been found in this area, being about eight times the average value.

• **SYMPOSIUM ON CHEMICAL REACTIONS IN THE LOWER AND UPPER ATMOSPHERE**—Stanford Research Institute will sponsor a Symposium on this subject to be held at the Mark Hopkins Hotel in San Francisco, April 18-20, 1961. Correspondence with regard to the conference should be addressed to R. D. Cadle, Stanford Research Institute, Menlo Park, California.

• **CURRENT ERUPTION OF MOUNT KILAUEA IN HAWAII**—In early October the Volcano Observatory in Hawaii National Park noted that their tiltmeters indicated surface bulges that sometimes culminate in eruptions. These bulges subsided for a time and finally redeveloped, and in November the volcano erupted and formed a lava lake within that portion of its crater called Kilauea Iki or 'Little Kilauea.' On December 22, it was reported that the eruptions had passed through 15 separate phases, each phase being accompanied by increased Earth tremors with fountains of hot gas and pumice and rosey-type of lava forming deep pools within the crater. In the fifteenth phase, the fountain of hot gasses and pumice rose to 1900 ft, and the temperature of the lava was reported at more than 2100 degrees Fahrenheit. It was reported that Crater Rim Road on the leeward side of the vent was buried under 100 ft of pumice, and elsewhere the pumice was 250 ft deep. The eruption of late December brought forth material estimated to be 55,000,000 cubic yards. A number of AGU members in residence in Hawaii, some of whom are connected with the Volcano Observatory, have been active in the studies of the behavior of the volcano, among these being Jerry P. Eaton and Gordon A. Macdonald.

Personalia

• **HORACE R. BLANK, Jr.**, recently studying at the University of Washington in Seattle, has received a postdoctoral fellowship from the National Sci-

ence Foundation for study at the University of New Zealand.

• **EDMUND BROMLEY, Jr.**, formerly Technical Di-

rector of the Directorate of Geophysics, Headquarters, Air Research and Development Command, has taken up duties as Technical Advisor in the newly created Office of Science and Technology, Deputy Chief of Staff for Plans, Headquarters, Air Research and Development Command, in Washington, D. C.

- DETLEV W. BRONK, President of the National Academy of Sciences and of the Rockefeller Institute, has received a special medal from the Society for Promoting International Scientific Relationships for his accomplishments in fostering the promotion of scientific research and international cooperation through scholarship exchanges.

- SIR EDWARD BULLARD of Cambridge University in England has been awarded the Arthur S. Day Medal of the Geological Society of America.

- SYDNEY CHAPMAN, who recently has been Chairman of the International Committee for the International Geophysical Year and since his retirement from Oxford University has devoted considerable time to special work at various colleges and universities in the United States, has recently served as Senior Research Scientist at the Institute of Science and Technology of the University of Michigan.

- HAROLD J. COOLIDGE, Executive Director of the Pacific Science Office of the National Academy of Sciences-National Research Council, has recently been awarded an honorary doctorate by George Washington University.

- MAURICE EWING, Director of the Lamont Geological Observatory and last Past President of the American Geophysical Union, has been named the first recipient of the new Vetlesen Prize recently established at Columbia University by the G. Unger Vetlesen Foundation for "outstanding achievement in the sciences resulting in a clearer understanding of the Earth, its history or its relation to the universe."

In citing the establishment of the Prize, it is noted that the Earth sciences, of great importance today, were of secondary concern when the Nobel prizes were established more than half a century ago. It is intended that the new Prize shall fill this important gap. The Prize consists of a gold medal, the sum of \$25,000, and the support of publication of the recipient's papers. Persons of any country may be nominated for the Prize which will be awarded every two years providing a worthy candidate is presented.

- PETER T. FLAWN is on leave of absence for three months from the Bureau of Economic Geology of the University of Texas and is serving as a Visiting Lecturer in Geology at Northwestern University where he is presenting a series of lectures on the application of petrography to tectonic problems.

- LAURENCE M. GOULD, President of Carleton College, has recently been honored by the Navy Department for achieving the closest cooperation between the Navy and civilian scientists during the recent IGY work in the Antarctic.

- G. EARL HARBECK, Jr., formerly Research Engineer of the General Hydrology Branch of the U. S. Geological Survey in Denver, has been appointed Branch Area Chief in the Denver area.

- HOLLIS D. HEDBERG, until recently Vice President of the Gulf Oil Company and now of the Geology faculty of Princeton University, has been named the new President of the Geological Society of America.

- J. ALLEN HYNK, has been appointed Director of the Dearborn Observatory and Chairman of the Department of Astronomy at Northwestern University.

- ADOLPH KNOPF, Professor of Geology at Stanford University, Stanford, California, has been awarded the Penrose Medal of the Geological Society of America.

- WILLIAM C. KRUMBEIN, Professor of Geology at Northwestern University, has received a Fulbright grant to present a series of lectures on sedimentary petrology at the University of London, where he will be affiliated with Queen Mary College. In addition, during his stay abroad he will visit other universities of the United Kingdom.

- GORDON G. LILL has left his work as Chief of the Geophysics Division of the Office of Naval Research and has taken up duties with the Raytheon Company of Newport, Rhode Island. Arthur E. Maxwell succeeds Mr. Lill in the Office of Naval Research.

- JOHN LYMAN has left his work as Oceanographer of the U. S. Navy Hydrographic Office and has taken up duties in connection with the oceanographic program of the National Science Foundation.

- HUGH ODISHAW, Executive Director of the U. S. National Committee for the IGY, has recently been cited by the Navy Department for his work in bringing about the closest cooperation between the Navy and civilian scientists in connection with the work in Antarctica.

- HAROLD V. PETERSON, until recently Denver Branch Area Chief of the General Hydrology Branch of the U. S. Geological Survey, has been named Staff Scientist in the General Hydrology Branch to devote full time to research and writing in the field of "Hydrology of the Public Domain."

- WILLIAM C. PHINNEY has been appointed Assistant Professor of Petrography and Petrology at the University of Minnesota. Formerly he was with the Chemistry and Petrology Branch of the U. S. Geological Survey.

- FRANK PRESS, Professor of Geophysics and Director of the Seismological Laboratory of California Institute of Technology, has been elected a member of the Board of United Electrodynamics, Inc., with headquarters in Pasadena.

- PAUL H. PRICE of the West Virginia Geological Survey represented the American Geophysical Union at the inauguration of Elvis J. Stahr, Jr., as the new President of the University of West Virginia on October 3, 1959.

- DONALD W. PRITCHARD, Director of Chesapeake Bay Institute of Johns Hopkins University, has been named to the Maryland State Board of Natural Resources.
 - LOUIS L. RAY is on leave from his duties with the U. S. Geological Survey, serving as Visiting Professor of Geology at Cornell University during the current academic year.
 - NORMAN H. RICKER has taken up duties as Professor of Physics at the University of Oklahoma.
 - MILTON S. SACHS, Hydraulic Engineer for the Bonneville Power Administration, has recently been on an assignment in Ethiopia as a Consultant to the United Nations where he will make a water resources survey of the Awash River valley to determine the potentials of flood control, irrigation, and general beneficial use of the waters.
 - ROBERT G. SNIDER has been appointed the coordinator of the forthcoming multinational oceanographic expedition to the Indian Ocean, which is being undertaken by the Special Committee on Oceanic Research of the International Council of Scientific Unions. He has established an office at 30 East 40th Street in New York.
 - JAMES S. SWEET, Staff Hydrologist of the U. S. Weather Bureau, has recently returned from South America, where he made a study of the proposed hydrometeorological networks of Chile and Ecuador for the United Nations.
 - JOHN VERHOOGEN of the University of California at Berkeley has been on a national Sigma Xi lecture tour presenting an address on the subject "Temperatures within the Earth."
 - HARRY WEXLER, research scientist of the U. S. Weather Bureau, who served as Executive Officer on the Antarctic program of the IGY, has recently been cited by the Navy Department for outstanding leadership in directing the weather services in Antarctica.
 - BRADFORD WILLARD, Professor Emeritus of Geology at Lehigh University, retired recently, is undertaking a study of a collection of 15,000 scientific periodicals left Lehigh University by Harvey Bassler, the collection known as the Harvey Bassler Collection. A grant of \$6600 has recently been given to the University by the National Science Foundation in support of the study.
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- CLINTON WILLITS WEATHERS ABBOTT, Bridge Engineer for the California Division of Highways in Sacramento, died March 17, 1958, at the age of 52. He was born in Washington, D. C. He attended Oregon State College for three years, pursuing courses in civil engineering and subsequently continued his studies through correspondence and extension courses. In 1937 he began his work with the California State Highways, serving in various capacities both on field and office work. He had been a member of AGU since 1953.
 - IRVING BALLARD CROSBY, Consulting Geologist of Boston, died September 18, 1959, at the age of 68. He took his baccalaureate degree from Massachusetts Institute of Technology in 1917 and his master's degree from Harvard in 1920. He devoted his entire career to work as a Consulting Geologist, serving the United States and several foreign governments in various capacities, also being a consultant to various industries. He was a specialist in engineering geology problems, including foundations. He had been a member of AGU since 1934.
 - CHARLES REINHARD FETTKER, Professor of Geology at Carnegie Institute of Technology and Cooperating Geologist with the Pennsylvania Geological Survey, died May 26, 1959, at the age of 71. He was born in San Francisco. He took his baccalaureate degree from the University of Washington in Seattle in 1910 and his master's degree and doctorate from Columbia in 1911 and 1914 respectively. He entered the service of the Washington State Geological Survey in 1909, and while a student at Columbia was an assistant and instructor in geology. In 1913 he began his duties at Carnegie Institute of Technology as an instructor, becoming a full Professor in 1929. He had special interests in various phases of economic geology but devoted considerable attention to the subsurface stratigraphy of the Appalachian Basin and other areas. He had been a member of AGU since 1936.
 - MURRY HACKMAN, Research Scientist in the Department of Meteorology at New York University, died July 12, 1959, at the age of 39. He took his baccalaureate degree from City College of New York in mathematical statistics in 1941, and pursued further studies in meteorology at the graduate level at New York University from 1950 to 1952. He took up duties at New York University in 1947 as a Research Associate on constant-level balloons and was promoted to the Research Scientist grade in 1950, continuing this work until the time of his death. He became a member of AGU in 1958.
 - HAROLD SCHJOTH PALMER, Professor Emeritus of Geology at the University of Hawaii, died October 24, 1959, at the age of 69. He was born in Cleveland, Ohio. He took his baccalaureate degree from Yale in 1912 and his doctorate from the same school in 1923. He studied at the University of Vienna in 1926-1927. He entered the service of the U. S. Geological Survey in 1914, continuing in various capacities until 1918 when he took up duties at Trinity College. He became Assistant Professor at the University of Hawaii in 1920, where he served continuously in various capacities until his retirement to the emeritus status in 1955. He also engaged in important hydrogeologic work for the Honolulu Board of Water Supply. He became a member of the American Geophysical Union in 1931.
 - ESME EUGENE ROSAIRE, owner of Subterrex and Senior Partner of Geochemical Surveys of Texas, died September 21, 1959, at the age of 62. He was

born in Chicago in 1897, took his baccalaureate degree from the University of Chicago in 1920. In 1921 he took his master's degree and in 1926 his doctorate from the same university. He undertook duties with the Western Electric Company from 1922 to 1925, and with the Geophysical Research Corporation from 1925 to 1932. From 1932 to 1936 he was President and General Manager of the Independent Exploration Company, and in 1937 organized Subterrex and subsequently Geochemical Surveys. He was considered one of the country's leaders in using geochemical methods in exploration. He had been a member of the American Geophysical Union since 1931.

• FRANCESCO SIGNORE, for many years Secretary of the Association of Volcanology of the Inter-

national Union of Geodesy and Geophysics and editor of *Bulletin Volcanologique*, died in Naples, Italy, December 2, 1959.

• RONALD M. WILSON, formerly Chief of Geodesy and Control Surveys in the Topographic Division of the U. S. Geological Survey, died November 28, 1959, at the age of 68. He was born in Quincy, Massachusetts, and took his baccalaureate degree from Massachusetts Institute of Technology in 1914. At this same time he entered the service of the U. S. Geological Survey, and except for military service during the First World War, he served continuously in the Survey until his retirement in 1956. He had been a member of AGU since 1934, and for several years served as Chairman of AGU's Committee on Budget.

Union, Section, and Committee Activities

Minutes of Executive Committee Meeting, American Geophysical Union November 14, 1959

The meeting was called to order at 09h 35m in the Reading Room of the National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C., by President Lloyd V. Berkner.

President—P. H. Abelson, Wm. C. Ackermann, L. H. Adams, Leroy R. Aldredge, L. V. Berkner, Walter H. Bucher, S. Douglas Cornell, Earl G. Drossler, Maurice Ewing, Irving Friedman, Floyd W. Hough, B. F. Howell, Jr., Woodrow C. Jacobs, J. W. Joyce, W. D. Lambert, H. E. Landsberg, Walter B. Langbein, John Lyman, Thomas F. Malone, Charles C. McDonald, Buford K. Meade, L. M. Murphy, J. H. Nelson, Hugh Odishaw, J. A. Peoples, Jr., John C. Reed, F. W. Reichelderfer, A. N. Sayre, J. Frank Schairer, Waldo E. Smith, and C. A. Whitten.

Approval of minutes—The minutes of the Executive Committee meeting held on May 3 and 6, 1959, published in the September 1959 issue of the *Transactions* (pp. 240-261), were approved.

General Secretary's Report

The last report of the General Secretary is recorded in the minutes of the Executive Committee meeting of May 3, 1959, published in the September 1959 issue of the *Transactions* (pp. 240-245). There have been a great many changes in the Executive Committee as of July 1 owing to the elections of new officers. There have been no changes because of changes in the Chairmanships of the Divisions of the National Academy of Sciences.

Actions of Executive Committee by mail ballot—Since the last meeting of the Committee, three lists (6th, 7th, and 8th) of new members and two corporation members have been approved by the Executive Committee by mail ballot. A ninth list of proposed new members will soon be submitted.

Since the last meeting of the Committee, grants totaling \$67,780.00 have been received from the National Science Foundation, the specific purposes for which will be noted later in this report. Also, a fund of \$2500.00 for payment of dues, subscriptions, and other matters for persons and organizations in certain Asian countries has been received from the Asia Foundation.

Organization of committees for the current triennium—Chairmen have now been appointed by the President for all special and standing committees except the Committee on Education. There is a crying need for some person who has the ca-

pacity and energy to organize a strong committee and get it functioning on this essential subject. Suggestions are invited. The new list of committees of the Union and also of the Sections, insofar as it is complete at this time, will be published in the December issue of the *Transactions*.

Publications—The monthly *Journal of Geophysical Research* has gone forward regularly, sometimes somewhat delayed but nonetheless without undue difficulty. The issues April to October, inclusive, have been distributed since our last report. The November issue will be released about mid-November and will be the largest yet, comprising 390 pages. The galley of the December issue are in hand and will be returned to the printer soon. Editors P. H. Abelson and James A. Peoples, Jr., are receiving the able assistance of Mrs. Rowena Peoples and Mrs. Lucile B. Stryker on the mechanics of editing and the aid of the office of AGU on proofreading as well as the business matters connected with the issuance of the journal. Information concerning Nos. 5 to 10 is as follows:

- May 1959 98 numbered pages of text plus 6 unnumbered pages, including 4 pages of paid advertising; edition of 8800
- June 1959 110 numbered pages of text plus 12 unnumbered pages, including 6½ pages of paid advertising; edition of 9000
- July 1959 168 numbered pages of text plus 8 unnumbered pages, including 1 page of paid advertising; edition of 9000
- August 1959 268 numbered pages of text plus 14 unnumbered pages, including 8 pages of paid advertising; edition of 9500
- September 1959 230 numbered pages of text plus 8 unnumbered pages, including 2½ pages of paid advertising; edition of 9500
- October 1959 284 numbered pages of text plus 12 unnumbered pages, including 7 pages of paid advertising; edition of 9200

The total paid subscriptions both through membership and special subscription continues to grow. Advertisements were carried in the October issues of six journals inviting subscriptions. Total paid subscriptions, including members, is over 7000.

Note the great increase in the number of pages beginning in August. It is anticipated that the December issue will be somewhat larger than the November issue, and will contain more than 400 pages. It will include the Symposium on Fluid

Mechanics in the Ionosphere held at Cornell University last July. In the August issue the Symposium on the Argus Experiment was published and in the November issue the Space Symposium of the National Academy of Sciences will appear. The total number of text pages for the current year 1959 will exceed 2400. In setting up the project a year ago, it was estimated that the JGR for 1959 would probably be 2400 pages.

Our printer (William Byrd Press in Richmond) has advised that there will be an increase in their charges to us for 1960 which will average between two and three per cent. This applies to both the *Journal of Geophysical Research* and to the *Transactions*.

The *Transactions* have been issued quarterly. The June and September numbers have appeared since our last meeting. The special information on these is as follows:

June 1959 122 numbered pages of text plus 6 unnumbered pages, including 1½ pages of paid advertising; edition of 9000

September 1959 110 numbered pages of text plus 8 unnumbered pages, including 1½ pages of paid advertising; edition of 9000. In addition, the directory of members (120 pages) was published in this issue.

The contents are presumably a matter of common knowledge of those here but special note should be made of the fact that we have continued to publish in each number of the *Transactions* three IGY Bulletins. These will presumably be discontinued in June 1960 and the size of the *Transactions* will be markedly decreased unless we are able to work out a plan to continue the publication of such material. The present inclusion in the *Transactions* is paid by the IGY and is without cost to the AGU, so if we continue similar material, we must obtain funds for its publication.

The translation of *Izvestiya* of the Academy of Sciences, USSR, Geophysics Series, continues under the able direction of W. S. Jardetsky, Translation Editor, who has organized an excellent panel of translators. Composition is done by McGregor and Werner. After checking by the Translation Editor, the bulletin is reproduced by offset. The first six numbers of 1958 have been published. Numbers 7, 8, and 9 are now being printed. All the numbers for 1958 have been translated and transmitted to the compositor. It is anticipated that the entire 1958 volume will have been completed by about the end of this year. Our grant for the continuation of the translation of this journal through its 1959 series has been received and we are hopeful that by mid-1960 we can complete the 1959 series and start in at once on the series for 1960. The subscription list for *Izvestiya* is about 250 and the edition printed regularly is 500.

Number 12 of *Izvestiya* for 1957 was finally released in the late spring or early summer, 1959. The final delay was due to the printing strike in England. The issue was finally printed by offset by Edwards Brothers in Michigan. The stock of the other eleven numbers has been received from Pergamon Press and arrangements for their storage and distribution from storage are being worked out. The stock of No. 12 is also being transmitted to us. No final settlement has been made with Pergamon Press. Before settlement can be made, the statement of subscriptions and other information on costs, etc. must be submitted by Pergamon, but it is hoped that this matter may be closed out without much additional delay. Although the printing of the 1958 translations is inferior to that of the 1957 translations, the consensus seems to be that this factor is more than offset by the greatly improved quality of the translations, and that the work as a consequence is of much greater service. The format and plan for the current issues was worked out by the office in cooperation with the Translation Editor and approved by the Russian Translation Board under the Chairmanship of Perry Byerly.

Since our last meeting, Geophysical Monographs No. 3 and 4 have been released and the final editing of Monograph No. 5 is progressing. Monograph No. 3 relates to a Conference on the Atmospheric Chemistry of Chlorine and Sulfur Compounds held in November 1957 with the aid of a grant from the National Science Foundation. A total edition of 1000 was run. The stock on hand is about 510 copies.

Monograph No. 4 is based on a Conference on Contemporary Geodesy held at Cambridge, Massachusetts in December 1958 with the aid of a grant from the National Science Foundation. This was released by the printer in early September. The total edition was 1400 and the stock on hand is about 680. All issues of the monograph series released thus far are still in stock. There is a fairly brisk sale of these.

Monograph No. 5 will be the largest of the series. It will contain the results of the Conference on the Physics of Precipitation held in Woods Hole, Massachusetts, in June 1959. The conference and the publication were supported by a grant from the National Science Foundation.

The new Geophysical Monograph Board established under the Chairmanship of Alan H. Shapley will take over the direction of the monograph series from No. 5 onward.

During the summer the Johnson Reprint Corporation completed the reprinting of Volumes 13-15, inclusive, of the *Transactions*. These volumes are now available through that company. In accordance with the contract arrangements our fragmentary back stock for 1956 was turned over to Walter J. Johnson, Inc. for storing and distribution, AGU receiving 50 per cent of list price on these back numbers.

Membership—Membership data as of November 2, 1959, are:

Membership as of April 2, 1959.....	5789	
Reactivated.....	9	
New members, April 21, 1959, to October 27, 1959, including 90 applications now being processed toward membership.....	298	6096
Resigned.....	24	
Inactive.....	1	
Dropped.....	175	
Deceased (reported since April 21, 1959).....	8	208
Total November 2, 1959		5888

Of these, 367 are student members and 94 life members. In addition, we have a total of 36 corporation members.

Attention is called to the fact that some of the student members are Captains, Lieutenant Commanders, Majors, and even Lieutenant Colonels, varying in age to 40 years or more. A question is raised as to whether an age limit or rank limit should be put on the student member grade. Incidentally, thus far a majority of the student members drop out when they are no longer eligible for student membership, though they are deemed to be automatically eligible for associate membership.

New brochures have been designed by Leo J. Stempson, Captain in the Air Force, under the direction of Earl Droessler, Chairman of the Committee on Membership and Willis B. Foster, Chairman of the Sub-Committee on brochures.

Dues unpaid—As of November 2, 1959, the following dues were unpaid:

Owe for 1959.....	208
Owe for part of 1959.....	9
Owe for 1958 and 1959.....	131
Owe for part of 1958 and all of 1959.....	0

Of the 130 persons who had not paid dues in full for 1957, reported at our last meeting, 106 have now been dropped.

Deaths—The following eight deaths have been reported to the office since our last meeting on May 3, 1959:

Clinton W. W. Abbott, March 17, 1958; Austin W. Zingg, April 7, 1959; Ivan R. Tannehill, May 2, 1959; Vernon D. George, August 3, 1959; James Edward Church, August 5, 1959; Norman Randolph Hagen, August 15, 1959; Alphonse R. Schmitt, August 28, 1959; and Irving B. Crosby, September 18, 1959.

Finances—The assets of AGU, as of October 1, 1959, are shown in the following accounts:

Riggs National Bank, checking account.....	\$ 3,052.43
Riggs National Bank, savings account.....	46,435.01
U. S. Series F Bonds (purchase price; mature value \$700).....	518.00
U. S. Treasury Notes, mature May 1960.....	50,000.00
U. S. Treasury Notes, mature August 1960.....	20,000.00
U. S. Treasury Notes, mature August 1960.....	50,000.00
Northwestern Federal Savings & Loan Association.....	10,099.03
Prudential Building Association..	10,221.18
Liberty Savings & Loan Association.....	2,399.58
Interstate Building Association...	10,197.27
Enterprise Federal Savings & Loan Association.....	10,000.00
Eastern Building & Loan Association.....	10,000.00
Home Building Association.....	10,000.00
Total	\$232,922.50

Below is an accounting of our assets as of October 1, 1959. Comparison is made with the two preceding years although it is recognized that because of the great change in circumstances during the current year, the comparison tends to be rather meaningless.

	Oct. 1, 1959	Oct. 1, 1958	Oct. 1, 1957
Current balance	\$ 89,568	\$ 9,097	\$17,728
Permanent Fund	19,338	15,000	14,055
Emergency Fund	1,000	1,000	1,000
T. M. & E. Award Fund	1,400	1,335	1,288
Russian Transla- tion Fund			
Izvestiya, 1957	7,350	11,188	40,067
Izvestiya, 1958	27,990		
Izvestiya, 1959	53,045		
Trudy	14,234		
Cloud Physics Conference	11,073	25,000	
Conference on Contemporary Geodesy	5,425		
Asia Foundation	2,500		
Totals	\$232,923	\$62,610	\$74,138

In accordance with the instructions of the Executive Committee, the funds of the Union not immediately needed have been placed at interest as shown above. Since the last meeting, the following investments have been made: U. S. Treasury Notes purchased August 5, 1959, maturing August 15, 1960, bearing 4% interest, \$20,000; U. S. Treasury Notes purchased August 27, 1959,

maturing August 15, 1960, bearing 4% interest, \$50,000.

The negotiable securities of AGU are now in safekeeping in a safety deposit box in Riggs National Bank in accordance with the action taken by the Executive Committee at its last meeting.

The budget, as approved at the last meeting of the Executive Committee, the minutes of which were published on pages 259-261 of the *Transactions*, has now been in effect for three months, which is perhaps insufficient to determine whether or not it will prove adequate in all regards. The Budget Committee will present its report to the Executive Committee later in this meeting.

The AGU operates on a fiscal year basis from July 1 to June 30. The regular publications of the Union, *JGR* and *Transactions*, however, operate on a calendar year which is also our dues year. Thus the AGU budget for these publications must be divided into consecutive half years. It may be worthwhile to consider whether this system could be simplified. The first six numbers of *JGR*, which were included in the 1959 budget, averaged 118 pages. Inasmuch as the budget allowed an average of 200 pages, there was a surplus in the 1959 fiscal year. Thus far in the last half of 1959, which is included in the 1960 budget, the individual numbers have averaged about 350 pages. If this higher volume of papers continues, the cost of publication will exceed the budget estimate for 1960. In accordance with plans, the subscription price for *JGR* has been raised to \$20.00 and has been so advertised.

Office staff—The office staff at the present time consists of four full time employees on appointment to permanent positions, James J. Capello, Ethel G. Sanders, Carol C. Akers, and Rebecca Traskey. In addition, Mrs. Martha Potter has been employed full time to help handle the heavy workload of the office caused by the increased subscriptions, the increased volume of proofreading, the work on the monographs, and related matters. Also, Glenda Quinn Olmstead, who has been with us part time for five years, is still working three to four days a week, and Om Bajaj, a graduate student from India attending George Washington University, is working part time. Waldo E. Smith, Executive Secretary, continues in direct charge of the office.

Quarters—Our lease for our present quarters at the AAAS Building expired on June 30 and a new lease has been entered into for the same quarters at an increased rate of \$4.75 per square foot per year.

International Matters—The Committee on International Participation has had two meetings since the last meeting of the Executive Committee, and it is anticipated that Chairman Joyce will make an extended report concerning the activities of the committee and international matters in general.

Work is progressing rapidly, both on the scien-

tific phases and the operating phases of the Twelfth General Assembly of the IUGG to be held in Helsinki, July 25-August 6, 1960. Circular No. 1 from Finland has been distributed to about 200 persons in this country and requests for information relating to the assembly continue. It would appear at this time as though our delegation will be on the order of 150 to 200 but it might even be larger.

In the intervening period some of the associations have held meetings. For example, the Association of Geodesy has held a series of symposia in various countries more or less comparable to the one on electronic distance measuring methods held at the time of our last Annual Meeting, and immediately following. The Association of Hydrology held a meeting in Germany this summer on forest influences and as noted in the September issue of the *Transactions*, pages 262-267, an extensive series of symposia will be held in connection with the meeting in Helsinki. Some, however, will precede the Helsinki Meeting, such as the meeting on new adjustment of European triangulation scheduled in Munich, May 1960, and another on aeronomy scheduled to be held in Copenhagen just preceding the Helsinki Meeting.

Meetings—The Committee on Cloud Physics of the Section of Meteorology, AGU, held a Symposium on Physics of Precipitation at Woods Hole, last June, attended by some 80 persons, including a number from as far away as Japan and Australia. The meeting was deemed to be an outstanding success.

The Pacific Northwest Regional group is scheduled to hold a meeting November 5-6, 1959, at Corvallis, Oregon. It was not possible for one of the National Officers of the Union to attend but Secretary C. C. McDonald of the Section of Hydrology attended officially on behalf of these officers. We will have a report from him later.

The Pacific Southwest Regional group will hold its annual meeting at the University of Southern California, February 4-5, 1960.

The AGU is participating quite actively this year in the meeting of the American Association for the Advancement of Science to be held in Chicago between Christmas and New Year's. Two committees are at work, one under the Chairmanship of John Simpson, arranging a symposium on the upper atmosphere to be held December 28. The second Committee is working in cooperation with the AAAS Committee for developing plans for a three-session symposium on current problems of the Great Lakes, which will be held on December 29 and 30. This Committee set up by W. C. Krumbein, one of AGU's representatives on the Council of AAAS, has W. S. Hamilton and M. B. Gamet, both of Northwestern University, as Co-Chairmen. It is hoped that these symposia will be well attended.

Plans for our own Annual Meeting for 1960 are developing well. It is contemplated that a symposium on aeronomy will be held jointly with

the National Academy and the IGY group. The symposium will start on Wednesday, April 27. The Section of Meteorology will meet jointly with the American Meteorological Society again and it is planned that their meeting will likewise start on the 27th. The general meeting period for the AGU, however, is April 28-30, inclusive, Thursday through Saturday.

Statutes and By Laws—The Statutes and By Laws, as amended to date, were published in the June issue of the *Transactions*, pages 151-155. Certain changes were approved by the Executive Committee relative to supporting memberships. This involves a change in the Statutes which must be laid before the NAS-NRC and our membership. We have postponed mailing out a ballot on this specific item as there are other prospective changes which might properly be included in the same mailing.

Miscellaneous—William J. Powell of the U. S. Geological Survey represented us at the inauguration of Leslie Stephen Wright as Twentieth President of Howard College in Birmingham, Alabama, April 21, 1959.

L. F. Warrick of the U. S. Public Health Service and Walton D. Durum of the U. S. Geological Survey represented us at Second National Conference on World Health, May 7-9, 1959.

The National Education Association held a conference at Lawrence, Kansas, in late June 1959. Frank C. Foley and James A. Peoples, Jr., represented the AGU. This was a conference similar to the one held in June 1958 at Bowling Green, Ohio, which a number of our members attended and found very helpful as outlined in the December issue of the *Transactions*, pages 1197-1198.

Patrick M. Hurley of MIT represented us at the inauguration of Asa Smallidge Knowles as President of Northeastern University, Boston, Massachusetts, on September 8, 1959.

George H. Chase, Thomas S. Lovering, Walter O. Roberts, and Alan H. Shapley represented us at Seventh National Conference of the U. S. National Commission for UNESCO, September 29-October 2, 1959.

Paul H. Price of West Virginia Geological Survey was our representative in the inauguration of Elvis Jacob Stahr, Jr., as President of University of West Virginia, October 3, 1959.

There are frequent calls from organizations for various details concerning geophysics or its applications. Our central office does its best to meet requests for information of this sort but on matters relating to education it is rather seriously handicapped by a lack of suitable literature.

A. NELSON SAYRE, General Secretary

Action on the General Secretary's report—The report was accepted.

Report and Comment of the President

The President discussed the plans of the IUGG for a world magnetic survey starting immediately

and continuing through the next sunspot minimum, pointing out that the Hydrographic Office already has plans under way for conducting an extensive magnetic survey over oceans and various land areas. These two endeavors complement each other and will be coordinated in so far as it is possible. He mentioned that the present magnetic maps were based to a large extent on interpolation of scattered earlier data with the survey of the early 1920's. A new survey at this time would provide much better data for deviation of secular variation. He noted that the Section of Geomagnetism and Aeronomy is already active in encouraging the world magnetic survey plan, and that this is of broad interest to geophysicists in view of its relation to our knowledge of the core. The Union will give it all possible support.

He mentioned that, as President, he had endorsed on behalf of the AGU the program of the U. S. Coast and Geodetic Survey to establish a new seismographic laboratory. He expressed the hope that the Executive Committee would support his action. A motion was made and passed unanimously that:

The American Geophysical Union strongly supports the establishment of an enlarged seismic effort and a supporting laboratory by the U. S. Coast and Geodetic Survey.

He noted the improved environment that had developed with respect to the sciences of Oceanography, Meteorology, and Seismology as a result of the endeavors of the Committee of the National Academy of Sciences to survey the scientific status of those fields and make recommendations. These studies were initiated at the request of interested governmental agencies. He mentioned informal discussions on the desirability of a similar Academy study in scientific hydrology. This would not be just another water-resources study, but a genuine attempt to evaluate the fundamentals of the water-resources problems. He called on General Secretary Sayre, who commented that previous studies have chiefly involved projects and costs and benefits, but there has been little fundamental study of hydrology as a science, and that we need basic research on the movement of water in the hydrologic cycle. The President then called on Walter B. Langbein, President of the Section of Hydrology, who endorsed the previous comments. He stated that of the total amount of money spent annually for the development of public and private facilities for the use and control of water in the United States, less than one-half of one per cent or \$25,000,000 is spent on collection and interpretation of basic hydrologic data. Data collection accounts for 90 per cent of this amount. Thus only 10 per cent or \$2,500,000 is being used for the interpretation of these data. A motion was made and passed unanimously that:

If a study of the capabilities and potential-

ties of scientific hydrology is undertaken by the National Academy of Sciences, this would have the strong endorsement and support of the American Geophysical Union.

The President noted that the American Meteorological Society has established a long-range planning committee and that he, as President of AGU, has been invited to attend the first meeting of the Committee. It was the consensus that the President should accept this invitation.

The President noted that much of the activity in the space sciences falls within the purview of geophysics excepting the part that relates to pure astronomy. Therefore, the AGU is very directly involved in space science. The Section of Geomagnetism and Aeronomy is especially involved, but the work likewise has a direct impact on geodesy, meteorology, and, perhaps as a consequence, hydrology. Very competent and highly respected scientists are involved in space activities. They will either form a splinter group or join with some established group such as AGU who will give them a satisfactory home. Most of these people have a background in the physical sciences, and they fit into geophysics very naturally. It was pointed out by Editor Abelson that many of their writings are coming to the *Journal of Geophysical Research*, the August 1959 issue having contained the Argus Symposium and the November 1959 issue the Space Symposium, both presented before the National Academy last spring. Charles A. Whitten noted that in the Section of Geodesy there has been a Committee on Satellites for two years and that the geometry and dynamics of space are very important to geodesy. L. R. Alldredge, President of the Section of Geomagnetism and Aeronomy, noted that the Section is keeping in touch with the people interested in space problems as represented by NASA, James Van Allen, and others, and that the symposium to be held jointly with the Academy (IGY group) next spring is being worked out by A. H. Shapley. There is a feeling that there should be not only a planned symposium but that time should also be allotted for contributed papers.

The President, in summing up the comments, noted he sensed the feeling that AGU should integrate the work of the space scientists with the field of geophysics. A motion was made and passed unanimously that:

The American Geophysical Union recognizes the importance of space science to the progress of geophysics and will, through its Sections, pursue space activities vigorously.

There was the further thought that a space committee might appropriately be appointed.

Standing Committees

International Participation—Chairman Joyce reported on the highlights of the meetings of the

IUGG Executive and Finance Committees held in Paris, September 21–26, 1959.

The Finnish Organizing Committee for the 12th General Assembly of the IUGG to be held in Helsinki, July 25–August 6, 1960, reported that arrangements were progressing satisfactorily. Accommodations are being planned for at least 1500 people. The meetings will be held at the University, which is right in Helsinki. A registration fee of approximately \$19 per person will be charged uniformly, including family members of delegates. A second circular on the meeting will be issued by the Finnish Committee about the end of 1959. This will provide complete information on hotel space, rates, and other pertinent information including reservation forms, which are to be returned to the Finnish Organizing Committee in Helsinki. A third circular giving the final agenda will be available to participants as they register at Helsinki.

A discussion took place concerning the organization under ICSU that is to be established to assure: (1) The most effective and expeditious use of IGY and IGC data and results, and (2) continuation of effective world-wide cooperation in projects involving geophysics and related sciences. This group was subsequently appointed at the ICSU meeting at The Hague, and is designated as the Comité Internationale Géophysique (CIG). Dr. Odishaw reports at greater length on the initial meeting of this group in a following section of these minutes.

Considerable discussion took place in Paris concerning the need for increased Union (IUGG) income. The most likely course of action will be an increase in the base subscription rate. Other techniques, such as increasing categories of membership of individual countries and bringing in new country members, do not promise much gain. This will undoubtedly be an active subject for discussion at Helsinki. A motion was made and passed that:

The American Geophysical Union recommends an increase in the base subscription rate of the International Union of Geodesy and Geophysics when this is shown to be properly justified and necessary.

The IUGG Executive Committee agreed on a general agenda outline to schedule a large series of symposia with a minimum degree of overlap. This will form the basis of a proposed agenda to be circulated by the General Secretary at an early date to adhering bodies.

It was noted that Cuba has applied for membership in the IUGG. A motion was made and passed that:

The U. S. National Committee should vote affirmatively on the application of Cuba for membership in the International Union of Geodesy and Geophysics.

The report of Chairman Joyce was accepted.

Chairman Joyce reported further that the Committee, at its meeting on November 13, 1959, had considered the suggestion by General Secretary Sayre that a Secretary for International Affairs should be appointed, noting here that there are contemplated changes in the policy of the National Academy with regard to the organization of National Committees. J. W. Joyce, W. W. Atwood, Jr., and A. Nelson Sayre were designated to study this situation with respect to the charter for the U. S. National Committee that was acted upon at the Executive Committee meeting last spring.

The General Secretary proposed to the Committee on International Participation that a Secretary for International Affairs be appointed. At its meeting on November 13, 1959, the Committee approved this proposal as set forth in Appendix 1. This will involve a change in the Statutes. A motion was made and passed that:

The proposal for a Secretary for International Affairs be approved.

The compilation of the U. S. report to the IUGG is in the hands of Leason H. Adams, who, as Editor, is arranging for the subject-matter reports. This is being done with financial assistance from the National Academy of Sciences. An application has also been filed with the National Science Foundation for funds for the final preparation and publication of the report.

Editor Adams noted that he has been receiving splendid cooperation from the Section officers with regard to the plan of the national report and that he is planning to get into immediate touch with persons who will be the actual authors of various portions of the report. It is expected that there will be some 70 subject-matter reports that will be oriented toward the scientific side of developments. It will be a document prepared for scientists rather than for libraries. He passed out the outline (Appendix 2) of the report and requested immediate word concerning modifications or subjects that have been omitted.

There was discussion concerning the issuance of an invitation to the IUGG to hold the 13th General Assembly in 1963 in the United States. The San Francisco area was mentioned as a possible site. The recommendation of the Committee on International Participation is that such an invitation should be made. It was agreed that if this recommendation is accepted by the National Academy of Sciences, the invitation should be issued as soon as possible. It was also recognized that arranging for an assembly in the United States will not be an easy job and that we would need to raise funds on the order of \$100,000 to \$125,000 in order to accomplish this. A motion was made and passed that:

The American Geophysical Union present to the National Academy of Sciences a proposal that the 13th General Assembly of the International Union of Geodesy and Geophysics be held in the San Francisco area.

The President advised that the officers will make an early study of this matter and will make recommendations to the Academy for a U. S. Organizing Committee.

With regard to the problem of a home for geochemistry among international organizations, J. Frank Schairer noted that the Association of Volcanology is the proper place but that it should be expanded to cover adequately the interests of geochemistry much as our own Section of Volcanology, Geochemistry, and Petrology has done in recent years. He noted that the Geochemical Society organized several years ago meets regularly with the Geological Society of America in the fall, and with the Section of Volcanology, Geochemistry, and Petrology in the spring. He felt that there is still need to expand our membership among the geochemists since the AGU offers them the best opportunity for discussion of their work. On the international scene, J. Tuzo Wilson, President of the IUGG, has appointed a working committee in geochemistry with Vinogradoff of the USSR as honorary chairman. L. T. Aldrich (U. S.) and L. R. Wager (U. K.) are organizing a symposium on age determinations to be held in Helsinki on July 27, and P. H. Abelson (U. S.) and C. W. Correns (Germany) are organizing a general session in geochemistry to be held July 25. A. Rittman, President of the Association of Volcanology, and J. Frank Schairer, Vice President, are designated as co-conveners, and Irving Friedman, Secretary of the Section of Volcanology, Geochemistry, and Petrology, has been taking steps to solicit papers for the Helsinki meeting as well as for the annual meeting next spring. Some members believe that the present framework of the Association of Volcanology is adequate to accommodate geochemistry, while others feel that it should be organized as a separate Association. The meeting of the needs of geochemistry requires not only accommodation in meetings but also facilities for publication. The President noted that there is a strong feeling of our Executive Committee expressed in the resolution at the last meeting and in the United States generally that a satisfactory forum should be provided for the geochemists in the IUGG.

Hugh Odishaw, Director of the World Data Center of the IUGG, attended a meeting at The Hague, November 4-6, 1959, on the problems of the future of the IGY endeavor. A detailed report of the results of this meeting will appear in the December 1959 issue of the *Transactions* (pp. 347-350), but here it is noted that a special inter-union committee of ICSU designated as CIG (Comité Internationale Géophysique or the International Geophysical Committee) has been established to wind up the IGY work and to lay plans for continuing international cooperation on the operational level along the lines of the IGY in various aspects of geophysics.

Thomas F. Malone mentioned that a World Congress in the Atmospheric Sciences is planned to be held in September 1961. At that time the

plans for the National Institute for Atmospheric Research (see *Transactions*, June 1959, pp. 95-111) will be largely crystallized and that IGY results in meteorology, including the effects of space science, will be coming out in volume. Accordingly, the time for such an international meeting will be opportune. Such a congress was already endorsed by various groups. A motion was made and passed unanimously that:

The American Geophysical Union endorses in principle the idea that an International Congress on Atmospheric Sciences be held at the appropriate time and that this has our strong support.

Budget—Chairman John C. Reed reported that on the basis of the three months July, August, and September, it was difficult to forecast whether the budget was working out as planned or not, noting that the volume of the *JGR* pages was low during the first months of the calendar year (in the last fiscal year) and is now steadily mounting. There is the appearance that the funds budgeted for the current fiscal year might not be sufficient as the budget approved for the year (see *Transactions*, September 1959, pp. 259-261) contemplated a smaller number of pages than the present trend would indicate. He noted that the *Transactions* pages (not counting the Directory) are also running larger than contemplated. It was the consensus of the meeting that:

Publication is a major phase of the work of the AGU, and that the *JGR* seems well on the way to becoming the world's leading geophysical journal. The AGU must therefore find the funds necessary to meet the needs.

At this point the President felt we should defer final action on the budget to review other problems that affect budget considerations.

Publications—Editors Peoples and Abelson presented a report (Appendix 3) which notes that in 1958 the bimonthly *Transactions* and the quarterly *JGR* together carried 1409 pages of scientific material. The total in the monthly *JGR* alone was 2460 in 1959, and they recommend that means be provided for 4200 pages in 1960, speaking here in terms of calendar years rather than fiscal years. It was noted that AGU can secure increased funds through five possible channels: (1) increasing membership dues, (2) increasing membership, (3) increasing advertising, (4) increasing the page charge, and (5) increasing the subscription rate. (There are, of course, other and minor sources of revenue such as increasing the rate for back issues.)

The outlook on costs for the *JGR* for the next three calendar years was then reviewed by Chairman Reed of the Budget Committee, which indicated that even to meet the earlier prospective number of pages (3000 pages per year) added revenue must be secured. It was agreed that the *JGR* must meet the needs of geophysics as an outlet for important papers and that further

measures for financing is the only alternative. A motion was made and unanimously passed that:

The Editors of the *Journal of Geophysical Research* be commended for the splendid work they have done and are doing on the *JGR*.

The Executive Secretary then presented a brief review of the *Transactions*, noting that this publication is a responsibility of the office. The *Transactions* endeavors to include material of importance to the progress of geophysics and to geophysicists. Extended reports on such activities as plans for the development of a National Institute of Atmospheric Research, plans for fundamental research in seismology, and drilling of a hole to the Mohorovicic discontinuity as articles, a few reviews, the contents of *Izvestiya*, a list of important new books, a list of English translations of Russian journals and books, notes and personalia, and Union, Section, and Committee activities, as well as the *IGY Bulletins*, have been included. Future issues will cover plans toward greater support of oceanographic research, Antarctic research progress, and the structure and operation of the IUGG. Critical comment on the contents of the *Transactions* was invited. It was noted that the *IGY Bulletin* would presumably cease in June 1960. The question was raised whether AGU should attempt to continue something of the same nature beyond that date. If so, funds for its compilation as well as its publication will be necessary.

It was noted that the *IGY Bulletin*, which appears in the *Transactions*, had been extended a year, to June 1960. It is yet uncertain as to whether the new committee for CIG will continue a similar monthly pamphlet, but it was the thought that this might be done and that a similar arrangement might be worked out whereby this material will be published on a no-loss—no-profit basis in the *Transactions* as the *IGY Bulletin* has been published. Possibly the Space Board of the National Academy of Sciences, in cooperation with the National Aeronautics and Space Administration, may be releasing a bulletin of the same general character covering the scientific results of space operations. The question was raised whether these two items might both be of interest for inclusion in the *Transactions*. It was the consensus that these would be desirable additions to the *Transactions*.

It was pointed out by the President that the present purpose of the *Transactions* is to keep scientists in touch with things that are going on in geophysics, and that the Executive Committee appears to favor continuing publication of bulletins on CIG and space research similar to the *IGY Bulletin*. A motion was made and unanimously approved that:

The Executive Committee endorses the continuation of materials of this kind on a no-loss—no-profit basis following the pattern of the *IGY*

Bulletin, using materials from the Space Science Board and from the CIG activities.

Hugh Odishaw noted that during the last year 100,000 student kits were sent out and that 3000 schools got IGY posters. He also noted that under the motion-picture project, 13 films are being prepared for presentation before high school groups, and that they should also be of interest to adults including those in science courses in college. An announcement of the availability of these is to be made in January. The question was raised whether they should be shown at the AGU meeting in the spring.

(The meeting then recessed for 45 minutes for lunch.)

In the absence of Chairman Byerly of the Russian Translation Board, the Executive Secretary outlined briefly the work actively in progress on *Izvestiya* of the Academy of Sciences, USSR, Geophysics Series, noting that the translations for the series for 1958 have been completed and work on the translations of the 1959 series is under way. The grant for 1959 has been received from the National Science Foundation. The first seven numbers for the 1958 series have been released (Nov. 14, 1959), nos. 8 and 9 should be released within the next two or three weeks, and composition and printing of the remaining three issues for 1958 should be complete by about the end of the calendar year. This work is undertaken on a no-gain-no-loss basis with 15% overhead. It appears on the basis of the present schedule that by mid-1960 the series for 1959 will be complete. If grant funds are available for continuation, we can be caught up to date as nearly as possible by the end of 1960.

Nos. 37 to 40 of *Trudy* of the Institute of Geophysics of Moscow are being translated and printed by Consultants Bureau under arrangements with AGU and with the aid of a grant from the National Science Foundation. These are being published as books under the merchandising plan of Consultants Bureau. It is the expectation that this may be a self-liquidating project.

Floyd W. Hough pointed out that the Russian publication, *Cartography and Geodesy*, contains much of live interest to geodesists. There should be at least selected translations available, but he does not favor cover-to-cover translations. He remarked that much material in geodesy that is being translated dates back to the last century. First attention should be given to current works such as *Cartography and Geodesy* which represent contemporary Soviet science. The General Secretary stated that if the Section of Geodesy felt that translation of *Cartography and Geodesy* was necessary, it might present a formal request to the Union.

Membership—Chairman Earl G. Droessler presented the new brochures for individual and corporation memberships, which were received

with much favorable comment. A motion was made and passed that:

The Executive Committee of the AGU officially extend its thanks to Leo J. Stempson, the designer of the new brochures for individual and for corporation memberships, for a job well done.

Chairman Droessler noted that we are now receiving new members at the rate of about 50 a month, and he feels that there are many more who are qualified and desire to become members. It is a matter of getting into touch with them. Many geochemists, meteorologists, and scientists in other fields are looking more and more upon *JGR* as being essential in their libraries.

There are now 367 student members. Less than half of the student members continue to be members upon the termination of their student status. Student dues for 1959 were \$3.00 based on our old publications. Now that we are publishing the *JGR*, the General Secretary was asked to review the student rate. The By-Laws provide that student members shall pay dues approximating the cost of a volume of the *Transactions* plus the cost of a volume of the *JGR*, the amount for each year to be fixed by the Executive Committee. The cost is now more than \$3.00, and the General Secretary was given authority to establish the new rate on the basis of this cost. (The cost for the printing of an added set of *JGR* plus *Transactions* for 1959 has been found to be \$4.20 which, with the added costs in the office, postage, etc., would bring the total to at least \$4.50 without taking into account the larger volume of *JGR* for 1960. Accordingly, the General Secretary has set the student dues for 1960 at \$4.50.) The Chairman of the Membership Committee said he would look into improved follow-up for transfer of student membership to membership. It was noted that approval was given at the last meeting to modify the Statutes to provide for Contributing Members, Sustaining Members, and Benefactors, but that the ballot on this has been withheld pending other prospective changes in the Statutes. Inasmuch as these other matters have been delayed, it was requested that the office proceed to ballot the membership on this matter as soon as possible.

The present member application form calls for references rather than for sponsors' signatures. It was requested that a card be sent to references to determine whether or not they endorse the candidate for membership.

President Berkner noted that we must consider at this time whether dues should be raised, though this cannot be done before 1961. John Reed pointed out that his income estimates were based on the dues for 1961 being established at \$12.00 as this was the basis for the application to the National Science Foundation for the grant to support our publications. It was noted in this regard that the material in Hydrology and Ocean-

ography has not increased in volume. It was also noted that in some other organizations, full members (or fellows) pay dues up to 50% greater than other members. Earl Droessler was asked to chair a committee to examine the level of the dues and report back at the time of the Annual Meeting of AGU. The President designated John C. Reed, B. F. Howell, Jr., Walter B. Langbein, and L. R. Alldredge as the other members.

Budget—The President announced that he had appointed a committee consisting of A. Nelson Sayre (Chairman, F. W. Reichelderfer, and John C. Reed to study and report on AGU salary scales and related matters pertaining to the effective functioning of the AGU office.

A brief report on advertising was given by the General Secretary. He noted there is the growing feeling that by accepting advertising both in the *Transactions* and in the *JGR* we have a tendency to "scatter our shots" in a way that reduces the appeal for potential advertisers. Our advertising representative recommends that we concentrate the advertising in the *JGR* except as prospective advertisers may request the *Transactions* as a medium. Decision on this matter was deferred for further information. The general question of advertising in the *JGR* was then discussed. AGU's advertising agents, Howland and Howland, have recently been merged with Paul V. Elsberry, a vigorous firm. Mr. Jack Boyd has taken over the AGU account and has started vigorous efforts to increase advertising. A major change in the fiscal situation may come from this effort.

After extensive discussion, a motion was made and approved that:

The page charge for the *Journal of Geophysical Research* be raised at once from \$15 to \$25 per page.

It was noted that the collection of the page charge for the first half of 1959 was about 80%, but that for papers of symposia it had not attained this figure. For the last half of the year in which three symposia appear the average is substantially less though the actual figures have not been tabulated.

The compilation of geomagnetic and solar data is done at the request of the Union and as a favor to it, so no page charges are involved. A question was raised about the publication of geomagnetic and solar indices as raw data in the *JGR*. It was noted that under the old management of *JGR* it had appeared there for many years, and geophysicists looked to *JGR* for these data. The Committee felt that at Helsinki the officers of AGU should suggest IUGG international publication of these data.

With regard to subscription rates, it was noted that the General Secretary in the past has set these rates in consultation with the officers and editors. The Committee felt that this should be left in his hands, with the feeling that all possible methods of decreasing the potential deficit

through adequate subscription rates should be developed.

There was further discussion of the Budget Committee's three-year summary, which indicates an increasing deficit each year with the diminution of funds received from the National Science Foundation and the increased publication requirements of *JGR*. It was noted that this was based on a conservative estimate of income and, except for the increasing number of pages in *JGR*, on a liberal outlay of expenditures. With the increase in total number of pages there will be increasing deficit, but in turn the increase in page charge will help to mitigate this circumstance which will require further study.

The report further called attention to a proposal that AGU adopt a health insurance program for its members similar to that adopted by the Geological Society of Washington. The Chairman reported that the Committee does not feel itself competent to review the proposal in detail and recommends that, if the matter is to be considered seriously by the Union, advice be sought from competent counsel and that the matter be studied by an *ad hoc* committee. This was referred to the officers for possible action.

A motion was made and approved that:

The three-year outlook prepared by the Budget Committee be accepted.

The President summarized the fiscal situation as follows:

(a) A Dues Committee to look into the question of dues under Earl Droessler is to report to the next meeting the desirable level of AGU dues.

(b) A Salary Committee under A. Nelson Sayre is to examine into adequacy of salary levels and related matters pertaining to the effective functioning of the AGU office.

(c) The page charge is increased from \$15 to \$25 per page.

(d) The General Secretary is to examine all matters relating to subscription rates and authorized to take appropriate action to raise them.

(e) The Membership Committee was starting a new drive to attract qualified members into AGU.

(f) A reorganized firm had taken over advertising and a vigorous drive on this score is under way.

(g) The finances must be put in good order before the NSF grant expired. We now have the egg in the form of a first-rate publication series, and we must now hatch effective financing in the next two years.

Meetings—Chairman Abelson noted that plans are developing for the annual meeting and that meeting rooms are being secured, but that the holding of meetings on Saturday interposes some difficulties and that we are undertaking this as an experiment. On the other hand, there are

advantages to holding our meetings in close relation to the Academy meetings. The meeting will open on Wednesday, April 27, with the Symposium on Solar-Upper Atmosphere Relations to be held jointly with the Academy, and with the opening of the sessions in Meteorology. A voice for Saturday meetings was expressed as favoring students as well as others from the universities who are not free to attend meetings during the week.

Charles C. McDonald reported as headquarters representative to the recent regional meeting of the Pacific Northwest Regional Division at Corvallis. The attendance was good but not as great as when the meetings are held in Seattle or Portland. The meeting in 1960 is scheduled to be held in October in Moscow, Idaho. He noted that in Portland the Hydrotechnical Society sponsored by the AGU group in that area has been highly successful in bringing individuals together to discuss various scientific and technological phases of hydrology, and that there is a plan to establish similar groups in Seattle, Corvallis, and Moscow to increase the contacts across the board in geophysics and with the student body.

At the AAAS meeting to be held in Chicago between Christmas and New Year's, AGU has developed a Symposium on the Upper Atmosphere and Solar Relations under the chairmanship of John A. Simpson and secretaryship of Stanley Ruttenberg. The AGU has also worked with the AAAS Committee in developing a Symposium on the Great Lakes Basin. The Committee is co-chaired by Wallis S. Hamilton and M. B. Gamet, with W. C. Krumbein and H. B. Gotaas as the other members. The Executive Secretary will attend as the representative of the AGU headquarters.

The Executive Secretary announced that the Pacific Southeast Regional Meeting will be held February 4-5, 1960, at the University of Southern California. President Walter B. Langbein of the Section of Hydrology will represent AGU headquarters at this meeting.

The meeting on solar-weather relationships is being arranged by E. H. Vestine and Walter Roberts on behalf of AGU's Committee on Cosmic-Terrestrial Relationships, the University of Colorado, and the University of California. It will be held either in mid-April in California or mid-May on the East Coast according to final decision of the Arrangements Committee.

Audit—A letter from Audit Committee Chairman A. G. McNish was read, noting that the job of auditing the accounts for the fiscal year ending June 30, 1959, is not yet complete. Chairman McNish recommended that AGU employ a professional firm to set up the accounts on the basis of the new scale of our operations as set forth in Appendix 4. A motion was made and passed unanimously that:

The recommendation of the Audit Committee be accepted that AGU employ a profes-

sional accountant to set up the accounts on the basis of the new scale of our operations, and further authorizing the officers to employ a part-time accountant if this seems desirable.

In connection with other audit matters, a question was raised in the Committee concerning the Union's investments and whether anything is done to hedge against inflation. The General Secretary pointed out that by far the bulk of the funds of the Union are short-term grant money. The Union's Permanent Fund totals only about \$20,000. This is now invested, in accordance with the instructions of the Executive Committee, in insured or guaranteed investments. This fund could be put into gilt-edge common stock, but if this is to be done it should be the responsibility, not of the General Secretary, but effectuated under the auspices of a thoroughly competent finance committee. Life-member payments are deposited in the Permanent Fund. The Permanent Fund is a guarantee underlying the Union's continued activity.

A motion was made and seconded that:

A Finance Committee be established to study the investment problems of the American Geophysical Union.

A tie vote was recorded. The President cast his vote in favor of the motion, stating that he did not express an opinion on change of investment but thought, in view of the division, that the matter should be studied. He then appointed F. W. Reichelderfer as Chairman, with Maurice Ewing, John Lyman, and John C. Reed as the other members of the Committee. It was noted further that the problems of life membership should be referred to Droessler's committee appointed to study the question of membership dues.

Special Committees

Award of the William Bowie Medal—In the absence of Chairman Gutenberg, Maurice Ewing, a member of the Committee, reported that Francis Birch of Harvard University has been selected as the Twenty-Second Recipient of the William Bowie Medal to be awarded at the annual meeting next spring. This nomination received the enthusiastic reception and confirmation of the Executive Committee.

Geophysical Abstracts—Chairman Lyman reported that the plan to set up parallel American Meteorological Society and AGU committees on this problem has not yet been accomplished. The AMS is cleaning up index work and then wants to develop a broad geophysical abstract plan. This has been delayed by the fact that the funds from the Air Force Cambridge Research Center for accomplishing the basic work has been decreased. The National Science Foundation fund has not yet been forthcoming because the Foundation wants plans developed so that this can be self-sustaining after a period of years. The AGU hard-

rock phase of an abstract journal has now been initiated, but the coverage so far is partial only. The policy of the AGI is to extend the activity successively to additional journals.

Adoption of the Metric System in the United States—Chairman Floyd Hough submitted a formal report as set forth in Appendix 5. He pointed out that, aside from the scientific needs, industrial pressures to change to the metric system are building up. Much of the world is now on the metric system, and the lack of the metric system in the United States affects our international trade.

Reports of Sections

Geodesy—In the absence of President Pierce and Secretary Meade, Vice President Floyd Hough noted that progress has been made on the recommendations for the Helsinki list of Academy delegates in Geodesy. The Coast and Geodetic Survey is proceeding actively in the preparation of a comprehensive report for Geodesy for the 12th General Assembly from which the report for the Union as a whole will be extracted.

Seismology—President Murphy noted that the plan of his group is to get in recommendations concerning delegates in about a week's time.

Meteorology—President Malone noted that previous discussions had covered reports essential to Meteorology.

Geomagnetism and Aeronomy—President Alldredge noted that over half of the *JGR* bears directly on Geomagnetism and Aeronomy. He noted further that the plans for the geomagnetic survey of the International Association of Geomagnetism and Aeronomy, as well as that of the Hydrographic Office, are very important. He also noted that a number from the United States are chairmen of committees or actively on committees of that Association.

Oceanography—In the absence of President Munk and Secretary LaFond, Oceanography was represented by John Lyman, who mentioned the recent Oceanographic Congress in New York. On the national scene, he felt that the recent NAS report and the steps to implement that report are very important, and felt that AGU should play a more important role in these activities. He noted that SCOR of ICSU is undertaking an oceanographic survey of the Indian Ocean. He commented further that according to the tabulation made by the editors the material in oceanography published in *JGR* has decreased about 10% from what it was in the *Transactions* in 1958, and hoped that steps can be taken to bolster the oceanographic contributions. The reasons for this situation were discussed, noting that the *Journal of Marine Research* and *Deep Sea Research* provide sharp competition for papers in oceanography but that our plan of very prompt publi-

cation should be an instrument in helping to secure more good papers in oceanography.

Volcanology, Geochemistry, and Petrology—Secretary Friedman noted that the Section's Committee on International Participation has met and is trying to organize the program for the Helsinki meeting to be complete by the first of January. The plans are to tie this in with the Geological Congress to be held in Copenhagen in August.

Hydrology—President Langbein noted that the Section is very active in the international scene and has collected some 30 excellent papers for the Hydrology meeting in Helsinki that will make a very worth-while contribution to the program on the part of the United States. He noted further that WMO has established a Committee on Meteorological Hydrology and that cooperation is being worked out on an international scale. On the domestic scene he indicated that he is doing all possible to allay the feeling that Hydrology is somehow being disregarded in the new publication plans, but that it is up to the hydrologists to make the best use of the facilities. With regard to suggestions of a National Academy study of hydrology, he feels that AGU should participate in this effort. F. W. Reichelderfer noted that in hydrology there is no international organization such as the WMO for meteorology. Accordingly, the WMO in its last Congress in April 1959 has brought hydrometeorology into the fields of activity of its organization, recognizing the close relationships and community of interest in many aspects of hydrology and meteorology. President Berkner mentioned that the Antarctic group has a strong interest in the glaciological phases of hydrology and that the hydrologists may wish to bring these more actively into the hydrologic activity. He noted incidentally that in Antarctic seismology there is perhaps a similar active group.

Affiliated Organizations

American Geological Institute—It was repeated that the American Geophysical Union should not be considered one of the supporting groups of the AGI, but that AGI is rather a counterpart group for geology with which we should maintain close liaison and cooperation. If there were an International Geological Union, then the AGI should be the U. S. National Committee to such a Union, just as AGU is the U. S. National Committee for the International Union of Geodesy and Geophysics.

Adjournment—There being no further business, the meeting adjourned at 15h 35m. The next regular meeting will be held in connection with the Annual Meeting of the AGU at Washington.

A. NELSON SATRE, *General Secretary*
WALDO E. SMITH, *Executive Secretary*

Appendix 1—Proposal for an AGU Secretary for International Affairs

It is proposed that a Secretary for International Affairs be appointed by the President of the AGU with the advice of the Executive Committee for an initial term of six years, and to be eligible for reappointment.

The Secretary for International Affairs will report directly to the President of the AGU, be a member of the Executive Committee, and have the following duties:

(1) Be responsible for planning and organizing AGU participation in international activities in which it is appropriately involved; for example, when acting in its capacity as the U. S. National Committee for the IUGG: This includes: (a) identification of issues and any matters that may

arise at international meetings involving the AGU; (b) preparation of U. S. positions on such issues and matters, as appropriate; (c) accomplishing the planning involved in the selection and designation of U. S. delegations; (d) briefing U. S. delegations, as appropriate; and (e) acting as the principal adviser to the Chief Delegate, and through him to the delegation, as appropriate, on international aspects of AGU participation in international scientific meetings.

(2) Be Chairman of the AGU Committee on International Participation.

(3) Provide the contact and coordination with Sections in their planning and participation in international aspects of their programs.

Appendix 2—Tentative list of topics for AGU Triennial Report to IUGG

Being compiled by LEASON H. ADAMS, *Editor of the Report*

Geodesy—The report for this subject will be a resumé of the more detailed report prepared at the U. S. Coast and Geodetic Survey for the International Association of Geodesy. The report may follow the pattern of the five or six named Sections of the Association.

Seismology and Tectonophysics (revised)—This is to be a joint report covering those major interests of the two Sections:

(1) Seismic instruments and planetary seismology. (2) Earth's crust in continents and below oceans. (3) Seismologic geography and related tectonophysics. (4) Magnitude and energy of earthquakes. (5) Seismic wave propagation. (6) Microseisms. (7) Internal constitution of the Earth. (8) Tectonic theories of continent formation and mountain building. (9) Flow, fracture, and strength of rocks in the laboratory. (10) Mechanism of isostatic compensation. (11) Theories of origin of earthquakes. (12) Heat flow and its tectonic consequences. (13) Geodetic measurements related to crustal movements and particular earthquakes. (14) Application of electronic computers to Seismological Problems. (15) Seismic surveying. (16) Earth tides.

Meteorology (revised)—(1) General circulation of atmosphere. (2) Numerical weather prediction. (3) Upper atmosphere studies. (4) Cloud physics. (5) Atmospheric electricity. (6) Chemistry of the atmosphere. (7) Polar atmosphere, Arctic. (8) Polar atmosphere, Antarctic. (9) Tropical meteorology. (10) Atmospheric radiation. (11) Satellite meteorology. (12) Climatology. (13) Past ice ages. (14) Statistical method.

Geomagnetism and Aeronomy—(1) General geomagnetism (Earth's main field). (2) Chemistry of the outer atmosphere. (3) Aurora (spectroscopic). (4) Aurora (phenomenologic). (5) Trapped energetic particles and the exosphere. (6) Air glow. (7) Geomagnetic and geoelectric variations. (8) Solar terrestrial relationships. (9) Ionosphere. (10) Cosmic rays.

Oceanography (revised)—(1) General oceanography: (a) on Atlantic temperatures; (b) on equatorial currents; (c) on deep currents; (d) on the theory of circulation; Antarctic oceanography. (2) Geochemistry of the oceans. (3) Ocean waves: (a) on surface waves; (b) on internal waves; Tsunami and storm surges. (4) Marine geophysics: (a) on seismic work; (b) on gravimetric work; (c) on magnetic work. (5) Marine geology: (a) relief of the sea floor; (b) ripples on the ocean bottom.

Volcanology, Geochemistry, and Petrology (revised)—(1) Active volcanoes, including thermal waters. (2) Experimental petrology, including the silicates, sulfides, and carbonates. (3) Behavior of earth materials under high pressure. (4) geologic-age determination. (5) Pleistocene chronology. (6) Deep-sea core studies. (7) Cosmic-ray effects in meteorites. (8) General geochemistry. (9) Stable isotopes in geology.

Hydrology—The report for this Section will be the responsibility of the Section's Secretary for International Participation, and will be prepared by the several Chairmen of Hydrology's Permanent Research Committees.

Appendix 3—Comparison of Number of Printed Pages of Geophysical Publications in 1958 and 1959

P. H. ABELSON and J. A. PEOPLES, JR., *Editors*

Field	1958 AGU	1958 JGR*	1959 JGR	Projected 1960
General	38		79	200
Geodesy	51		171	400
Seismology	37		107	200
Meteorology	101		177	300
Geomagnetism and Aeronomy ^b	38	588	1237	1900
Oceanography	115		104	200
Volcanology, Geo- chemistry, and Petrology	56		164	320
Hydrology	345		326	500
Tectonophysics	40		95	180
	821		588	
Total pages	1409		2460	4200

During 1959 the Journal of Geophysical Research published 261 Scientific Papers, 48 Letters to the Editor, 3 sets of Abstracts, in addition to the Report of the Committee on Cosmic-Terrestrial Relationships and Geomagnetic and Solar Data.

* Adjusted to reflect fact that old JGR had only two-thirds as many words per page as new journal.

^b This classification includes Geomagnetism, Aeronomy, and Space Physics (all very broadly defined).

Appendix 4—Preliminary Report of the Committee on Audit for the Fiscal Year Ending June 30, 1959

A. G. McNISH, *Chairman*

A. P. CRARY

E. B. ROBERTS

Your Committee on Audit has examined the books of the American Geophysical Union for the fiscal year ending June 30, 1959, and found them to be essentially in agreement with the financial statement submitted by the Executive Secretary. However, there are certain minor changes which the Committee feels should be made in the form of the statement, and therefore is not in a position to submit a final report at the present time.

Your Committee begs to call to your attention and to the attention of the Executive Committee that the financial statements of the Union now run up close to a third of a million dollars. Under

these circumstances, the methods of accounting which have been followed now for the past 30 years or so may not be the most suitable. The Committee feels that the Executive Committee should give consideration to the desirability of seeking some professional advice on setting up a system which will simplify the procedures at present followed.

The Committee wishes to assure you that this expression of opinion in no way reflects upon the care and thoroughness with which the accounts of the Union have been kept, only that under the circumstances professional guidance in this field may be desirable.

Appendix 5—Second Progress Report of the Special Committee for the Study of the Metric System in the United States

FLOYD W. HOUGH, *Chairman*

CARL I. ASLAKSON
FINN E. BRONNER
JOHN G. FERRIS

HELMUT E. LANDSBERG
G. MEDINA
JOHN A. O'KEEFE
L. V. JUDSON, *Consultant*

MILTON O. SCHMIDT
LANSING G. SIMMONS
GEORGE E. WHITMORE

Reference is made to the first Progress Report presented in May 1959 to the Executive Committee of the Union, published in the *Transactions* (September, pp. 256-258 with addendum and revision of the Table in December, pp. 371-372). The Committee as previously constituted was reappointed by President Berkner and directed to continue its efforts during the fiscal year 1959-1960.

During the 1959 Business Session of the Union, the Committee-proposed resolution was passed unanimously (*Trans.*, June, 1959, p. 141); this resolution placed the A.G.U. on record in favor of the adoption of the Metric System as the "only official system" of Weights and Measures in the United States effective 33 years after passage of appropriate legislation by the Congress.

One meeting of the Special Committee has been held since the May report. The previous plan of procedure was considerably altered due to most welcome but unanticipated 'metric' action in the Congress, both in the Senate and in the House, the first such activity in nearly 30 years. H.R. 7401 introduced in May by Mr. Brooks and S. 2420 introduced in July by Mr. Neuberger both call for feasibility studies of the Metric System by an appropriate Government agency. A third action of interest was the introduction also in July of House Concurrent Resolution 364 by Mr. Fuller, which would place the Congress on record in favor of the Metric System. All three bills were referred to appropriate committees. Since both the Senate and House bills would provide

funds for a comprehensive study by the Department of Commerce, our Committee felt that it should not proceed further with our own questionnaire survey of the non-scientific public, as planned but, instead, should offer its support and information files to the appropriate Committees of Congress. This was done by correspondence with the authors of the Senate and House bills, who subsequently expressed their appreciation for the Committee's offer of assistance.

The Committee has now received a total of 1080 completed questionnaires, an analysis of which will appear in the December 1959 issue of the *Transactions* (pp. 371-372). Since the percentage favoring change-over to the Metric System is about 90% and this has not changed appreciably since the analysis of the first 500, we may assume that we have reached the point of 'diminishing return' as far as polling of the engineering and scientific field is concerned. We do not contemplate further solicitation of questionnaires.

The expenditures by the Committee have been minor, about \$20.00 in connection with correspondence and \$20.00 for the printing of questionnaires, during current fiscal year.

As indicated above, the Committee is now in a more or less 'stand-by' situation in view of the bills pending before the Congress. It plans to assist the pertinent Committees of Congress if invited to do so, to maintain necessary correspondence, and to resume its authorized studies if the desired action is not forthcoming in the Congress.

Meeting of the U. S. National Commission for UNESCO

The United States National Commission for UNESCO met in Denver, Colorado, September 29-October 1, 1959. The American Geophysical Union was represented by Alan H. Shapley, Walter Orr Roberts, George H. Chase, and Thomas S. Lovering. The theme of the meeting was "The Cultures of the Americas." Mr. Shapley, reporting on the meeting, noted that he attended a session that was largely devoted to an exposition of the activities of various governmental and non-governmental organizations in South America which tend to point up the need for intelligent assistance in the development of the underdeveloped areas. He notes that his purpose in attending this session was to call to the attention of those at-

tending the great part that geophysics and especially the IGY played in encouraging the development of the indigenous scientific resources of various countries, and was afforded five minutes to develop this theme. He believes that it served to help clarify the role of UNESCO in the IGY enterprise which, though small, was significant in that it made possible the early activity of the CSAGI committee.

Dr. Roberts attended the opening plenary session on September 29 and two panel sessions on the succeeding days involving science in the Americas, which included the session chaired by Merle Tuve. One of the problems of science in Latin America is the matter of stability of the

scientific institutions and the difficulty in retaining top scientific people. Thus one of the major obstacles is the need for the development of sustained research programs of high caliber. On the other hand, he noted considerable optimism on the part of the people involved in the discussions, particularly the interesting work developing from existing inter-American organizations dedicated to the improvement of scientific and cultural relations. He felt that no small part of this activity in the sciences stems from Dr. Tuve's personal enthusiasm.

Dr. Roberts noted that AGU's function might appropriately be to aid in fulfilling substan-

tial need for ties with specific scientific institutions in Latin America, and that these ties might serve to stabilize some of the government-sponsored Latin American institutions of science. He pointed out one spectacular success, namely, the Huancayo Magnetic Observatory in Peru. A number of years ago this was turned over to the Peruvian government by the Carnegie Institution of Washington which established it. The new high altitude station of Dr. Escobar needs close and active cooperation together with further assistance from North American institutions in providing scientific equipment and a measure of formal ties.

Meetings of the Geophysical Society of Hawaii

The Geophysical Society of Hawaii, whose officers serve as the Regional Committee of the AGU in the Mid-Pacific area, has continued to hold evening meetings through the fall and winter months. On October 15, the topic was "The Oceanic Crust: A Discussion of the Structure and Development of the Floor of the Oceans," presented by Ralph M. Moberly, Jr., of the Department of Geology and Geophysics of the University of Hawaii. On December 10, the general theme of the meeting concerned bauxite. Three papers were presented as follows: "Geological Aspects of Bauxite Formation" by A. Abbott of the Geology Department of the University of Hawaii; "Moisture Regimes in Bauxite Weathering"

by G. D. Sherman, Professor of Soil Science of the University of Hawaii; and "The Possible Significance of Erosion in Bauxite Mining" by B. D. Van't Woudt, Assistant Agricultural Engineer of the University of Hawaii.

New officers have been elected by the Society as follows: Nicholas H. Chavasse, Colonel, U. S. Air Force, President; Saul Price, U. S. Weather Bureau, Vice President; Bessel D. Van't Woudt, Secretary-Treasurer; Frank N. Visser, U. S. Geological Survey, Councilor. Walter R. Steiger, currently a Councilor, has been absent on the mainland, and Thomas S. Austin has been serving as Councilor during his absence.

Pacific Northwest Regional Meeting

The annual meeting of the Pacific Northwest Regional group was held in Corvallis, Oregon, November 5 and 6, 1959, with some 100 in attendance. Eighteen papers were presented. The Pacific Northwest Region has been instrumental in developing local hydrotechnic societies in Portland and plans to extend this activity to other

centers where there is particular interest as an AGU-sponsored endeavor. The intent is to increase frequent contacts across the board in geophysics, not only among workers and teachers in the field but with students as well. It is planned that the next meeting of the Region will be held in Moscow, Idaho, in the fall of 1960.

Chicago Meeting of AAAS

In connection with the annual meeting of the American Association for the Advancement of Science in Chicago, the AGU held a two-session Symposium on the Upper Atmosphere and Solar Relations, arranged by John A. Simpson of the University of Chicago and Stanley Ruttenberg of the U. S. National Committee for IGY. These sessions were held on December 28, with about 100 attending the morning session and somewhat more attending the afternoon session. Nine papers were presented in all.

The AGU also joined with Section E, Geology, of the Association in arranging a Symposium on the Great Lakes Basin. Our committee for this was Wallis S. Hamilton and M. B. Gamet of Northwestern University as Co-Chairmen, and

W. C. Krumbein and H. B. Gotsas also of Northwestern as other members. The AAAS committee consisted of George B. Maxey and Jack L. Hough. Eighteen papers were presented in three sessions on December 29 and 30. About 150 were in attendance in the first morning session, over 100 in the afternoon session, and about 75 at the third session.

In addition, Section M held a symposium on the Metric System on December 28. The Executive Secretary presented a summary of the report by our Metric Committee that appeared in the September 1959 issue of the *Transactions*, pages 256-258, with addendum and revision in the December 1959 issue, pages 371-372.

Union and Section Committees

EXECUTIVE COMMITTEE OF THE UNION

Lloyd V. Berkner, President; F. W. Reichelderfer, Vice President; A. Nelson Sayre, General Secretary; Waldo E. Smith, Executive Secretary; Philip H. Abelson, John N. Adkins, Leroy R. Allredge, Wallace W. Atwood, Jr., K. Hilding Beij, Hugo Benioff, Detlev W. Bronk, Walter H. Bucher, Horace R. Byers, Earl G. Droessler, Maurice Ewing, Irving Friedman, H. Richard Gault, Harry H. Hess, Benjamin F. Howell, Jr., Patrick M. Hurley, Woodrow C. Jacobs, Henry R. Joesting, J. W. Joyce, Joseph Kaplan, Eugene C. LaFond, Walter D. Langbein, Helmut E. Landsberg, Walter B. Langbein, Ray K. Linsley, Thomas F. Malone, Charles C. McDonald, A. G. McNish, Buford K. Meade, Walter H. Munk, Leonard M. Murphy, J. H. Nelson, Alfred O. C. Nier, Brian O'Brien, Charles Pierce, John C. Reed, Roger R. Revelle, J. Frank Schairer, Milton O. Schmidt, H. Burr Steinbach, E. H. Volwiler, Charles A. Whitten, and Harold G. Wilm

STANDING COMMITTEES OF THE UNION

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Statutes and By-Laws—K. Hilding Beij, Chairman; Walter B. Langbein and Charles A. Whitten

Membership—Earl G. Droessler, Chairman; John R. Gerhardt, Chairman, Subcommittee on Student Memberships; Willis B. Foster on Brochures; Howard T. Orville on Corporations; Elliott B. Roberts on Government Memberships

Meetings—~~Philip H. Abelson~~, Chairman

Nominations—Walter H. Bucher, Chairman; J. Frank Schairer and E. H. Vestine

Budget—John C. Reed, Chairman; L. T. Aldrich and Louis O. Quam

Audit—A. G. McNish, Chairman; A. P. Crary and Elliott B. Roberts

SPECIAL COMMITTEES AND BOARDS OF THE UNION

Geophysical and Geological Study of Continents—George P. Woollard, Chairman; W. E. Bonini, R. A. Geyer, Sigmund Hammer, J. C. Harrison, P. M. Hurley, M. J. S. Innes, H. R. Joesting, Gordon G. Lill, Paul L. Lyons, J. A. Peoples, Jr., Frank Press, Donald A. Rice, Nelson C. Steenland, J. Tuzo Wilson, and J. Lamar Worzel

Cosmic-Terrestrial Relationships—E. H. Vestine, Chairman; Walter Orr Roberts, Vice Chairman; Robert Bracewell, Joseph W. Chamberlain, C. T. Elvey, John W. Evans, Herbert Friedman, Sigmund Frits, H. K.

Kallmann, S. A. Korff, Robert R. McMath, M. G. Morgan, Hugh Odishaw, C. E. Palmer, A. H. Shapley, S. F. Singer, Joseph Smagorinsky, Thomas L. Skillman, Arthur H. Waynick, Fred L. Whipple, and Hurd C. Willett
Award of the William Bowie Medal—~~Beno Gutenberg~~, Chairman; Walter M. Elsasser and Maurice Ewing (Dr. Gutenberg died January 25, 1960) ~~Chairman~~ L. R. Aldrich

Resolutions—Helmut E. Landsberg, Chairman; David T. Griggs, Norman A. Haskell, and E. B. Roberts

Education—Appointments pending

Award in Terrestrial Magnetism and Electricity—Frederick J. Agnich, Chairman; other appointments pending

Tellers—James N. Jordan, Chairman; Bernard C. Byrnes, Robert B. Guillou, James F. Lander, H. W. Oliver, Robert G. Schmidt, B. W. Seaton, and Harris B. Stewart, Jr.

Study of the Metric System—Floyd W. Hough, Chairman; Carl I. Aslakson, Finn E. Bronner, John G. Ferris, Helmut E. Landsberg, G. Medina, John A. O'Keefe, Milton O. Schmidt, Lansing G. Simmons, and George W. Whitmore; L. V. Judson, Consultant

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Salaries and Organization—A. Nelson Sayre, Chairman; John C. Reed and F. W. Reichelderfer

Finance and Investment—F. W. Reichelderfer, Chairman; Maurice Ewing, John Lyman, and John C. Reed

Dues—Earl G. Droessler, Chairman; L. R. Allredge, B. F. Howell, Jr., Walter B. Langbein, and John C. Reed

REGIONAL COMMITTEES

North Central Regional Committee—Rudolph A. Black, Harry C. Bolon, Wayne L. Decker, Joseph W. Howe, Philip W. Kenworthy, Mar-

- tin E. Nelson, Robert J. Pafford, Jr., Robert H. Shaw, and Athelstan F. Spilhaus
 Pacific Southwest Regional Committee—Eugene N. Bollay, Chairman; W. D. Duthie, Secretary
 Representing Hydrology—Arthur F. Pillsbury, Joseph F. Poland, and David K. Todd
 Representing Oceanography—Henry W. Menard and Jacob B. Wickham
 Representing Meteorology—W. D. Duthie, Eugene Bollay, and Robert E. Holzer
 Representing Geomagnetism and Aeronomy—E. H. Vestine
 Pacific Northwest Regional Committee—Ned Bethlahmy, Chairman; Donald W. Kuehl, Secretary-Treasurer
 Representing Geodesy—Ector B. Latham
 Representing Seismology and Tectonophysics—Mark F. Meier
 Representing Meteorology—Donald W. Kuehl and Melvin J. Ord
 Representing Geomagnetism and Aeronomy, and Volcanology, Geochemistry, and Petrology—Keith B. Anderson
 Representing Oceanography—Ned Bethlahmy
 Representing Hydrology—Thomas H. Campbell, Albert M. Moore, and Calvin C. Warnick
 Mid-Pacific Regional Committee (Geophysical Society of Hawaii)—Nicholas H. Chavasse, President; Saul Price, Vice President; Bessel D. Van't Woudt, Secretary-Treasurer; Thomas S. Austin (in the absence of Walter R. Steiger) and Frank N. Visser, Councilors

REPRESENTATIVES

- NAS-NRC, Division of Earth Sciences—Frank Press
 NAS-NRC, Division of Physical Sciences—L. T. Aldrich
 NAS-NRC, Office of Critical Tables—George R. Tilton
 American Association for the Advancement of Science, Representatives on the Council—W. C. Krumbein and A. Nelson Sayre
 American Geological Institute, Board of Governors—James R. Balsley and Walter H. Bucher

COMMITTEES OF THE SECTIONS

Geodesy

- Executive Committee—Charles Pierce, Chairman; Floyd W. Hough, Buford K. Meade, and Milton O. Schmidt
 International Participation—Charles A. Whitten, Chairman; Executive Committee
 Resolutions—Frank L. Culley, Chairman; A. Edward Craig and Roy O. Williamson
 Program—Erwin Schmid, Chairman; Claude F. Gilchrist, John A. O'Keefe, and Donald A. Rice
 Nominations—Milton O. Schmidt, Chairman;

Albert J. Hoskinson, Gunnar Leifson, and Julius L. Speert

Seismology

- Executive Committee—L. M. Murphy, Chairman; Hugo Benioff, B. J. Howell, Jr., and J. A. Peoples, Jr.
 International Participation—L. M. Murphy, Chairman; Jack E. Oliver and James T. Wilson
 Resolutions—George H. Sutton, Chairman; P. E. Byerly and David E. Willis
 Nominations—Hugo Benioff, Chairman; Ross R. Heinrich and Carl F. Romney

Meteorology

- Executive Committee—Thomas F. Malone, Chairman; Gordon E. Dunn, Woodrow C. Jacobs, and Helmut E. Landsberg
 International Participation—Horace R. Byers, Chairman; Earl G. Droessler, Robert D. Fletcher, W. W. Kellogg, H. E. Landsberg, and Sverre Pettersen
 Upper Atmosphere—Harry Wexler, Chairman; Frank Johnson, Joseph Kaplan, W. W. Kellogg, Homer E. Newell, Jr., and Fred L. Whipple
 Atmospheric Diffusion—Morton L. Barad, Chairman; F. I. Badgley, James Edinger, Heinz Lettau, and Lester Machta
 Atmospheric Chemistry—James P. Lodge, Chairman; W. D. Crozier, Joshua Z. Holland, and Christian Junge
 Cloud Physics—Helmut Weickmann, Chairman; Charles E. Anderson, Roscoe R. Braham, Jr., Dwight Kline, J. E. McDonald, Joanne S. Malkus, and Vincent J. Schaefer
 Biometeorology—Appointments deferred
 Interactions of the Atmosphere with the Sea (joint committee with the Section of Oceanography and the American Meteorological Society)—Dale F. Leipper, Chairman; John Lyman, Walter H. Munk, Gerhard Neumann, and William S. Von Arx
 Nominations—Appointments deferred
 Program for Joint AMS-AGU Spring Meeting, 1960—Fred D. White, Chairman; James K. Angell, Richard Gill, Jack Hinkleman, Arthur Johnson, and Conrad P. Mook

Geomagnetism and Aeronomy

- Executive Committee—L. R. Alldredge, Chairman; C. T. Elvey, H. R. Joesting, and J. H. Nelson
 International Participation—L. R. Alldredge, Chairman; C. T. Elvey, H. R. Joesting, J. H. Nelson, W. O. Roberts, and E. H. Vestine
 Space Fields—Gerhard F. Schilling, Chairman; J. P. Heppner, S. F. Singer, and E. H. Vestine
 Rapid Variations—Elwood Maple, Chairman; Victor P. Hessler and Robert E. Holser
 Upper Atmosphere—J. W. Chamberlain,

Chairman; R. A. Helliwell, F. S. Johnson, and Franklin E. Roach
 Nominations—Appointments deferred
 Resolutions—Appointments deferred

Oceanography

Executive Committee—Walter H. Munk, Chairman; Eugene C. LaFond, D. W. Pritchard, and Roger R. Revelle
 International Participation—D. W. Pritchard and John Lyman
 Interactions of the Atmosphere with the Sea (joint committee with the Section of Meteorology and the American Meteorological Society)—Dale F. Leipper, Chairman; John Lyman, Walter H. Munk, Gerhard Neumann, and William S. Von Arx
 Nominations—Appointments deferred
 Resolutions—Appointments deferred

Volcanology, Geochemistry, and Petrology

Executive Committee—Alfred O. C. Nier, Chairman; Irving Friedman, J. Frank Schairer, and Francis J. Turner
 International Participation—Alfred O. C. Nier, Chairman; L. T. Aldrich, Irving Friedman, Samuel Goldich, J. Frank Schairer, and Robert L. Smith
 Nominations—Appointments deferred
 Resolutions—Appointments deferred

Hydrology

Executive Committee—W. B. Langbein, President; W. C. Ackermann, Vice President; C. C. McDonald, Secretary; R. K. Linsley, Past President; W. E. Hiatt, at large; H. F. Blaney, at large; H. E. Schwarz, Meetings; R. N. Wilson, International Participation; Tor J. Nordenson, Publication Liaison; H. G. Wilm, as President, International Association of Hydrology; A. N. Sayre, ex officio; and Waldo E. Smith, ex officio
 International Participation—Executive Committee with R. N. Wilson designated as Secretary

Program—Harry E. Schwarz, Chairman
 Nominations—Appointments deferred
 Awards—Harry F. Blaney, Chairman; Alfred J. Cooper, G. Earl Harbeck, Floyd A. Huff, Mark F. Meier, C. C. Warnick, and M. G. Wolman
 Precipitation—Floyd A. Huff, Chairman; Richard Tarble (1960), Homer Hiser (1960), David Hershfield (1960), P. B. McCready (1961), M. C. Boyer (1961), and Wayne L. Decker (1961)
 Evaporation and Transpiration—G. Earl Harbeck, Chairman; Irwin Remson (1960), R. C. Culler (1960), T. J. Nordenson (1960), R. L. Lowry (1961), W. J. Roberts (1961), and J. B. Franzini (1961)
 Snow—C. C. Warnick, Chairman; Livingston Lansing (1960), James A. Bender (1960), and R. W. Gerdel (1960)
 Erosion and Sedimentation—M. G. Wolman, Chairman; D. D. Smith (1960), R. L. Shreve (1960), and Thomas Maddock, Jr. (1960)
 Surface Water—Alfred J. Cooper, Chairman; M. M. Richards (1960), M. S. Sachs (1960), W. J. Roberts (1960), C. L. Barker (1961), E. A. Johnson (1961), and Walter Hofmann (1961)
 Ground Water—George B. Maxey, Chairman; S. N. Davis (1960), J. D. Hem (1960), D. V. Deere (1960), H. C. Storey (1961), H. G. Hershey (1961), and J. B. Graham (1961)
 Glaciers—M. F. Meier, Chairman; Henri Bader (1962), A. P. Crary (1962), R. P. Goldthwait (1962), E. R. LaChapelle (1962), and R. P. Sharp (1962)

Tectonophysics

Executive Committee—Patrick M. Hurley, Chairman; Clarence R. Allen, Iris Y. P. Borg, H. Richard Gault, Harry H. Hess, and L. B. Slichter
 International Participation—H. Richard Gault
 Nominations—Appointments deferred

SPECIAL ANNOUNCEMENTS

• FRANCIS BIRCH NAMED TWENTY-SECOND WILLIAM BOWIE MEDALIST—Francis Birch, Sturgis-Hooper Professor of Geology of Harvard University, has been named at the Executive Committee meeting on November 14, 1959, as the Twenty-Second William Bowie Medalist in recognition of his outstanding work in many phases of geophysics. The award will be made at the time of the Forty-First Annual Meeting of AGU in Washington, D. C., next April.

• FORTY-FIRST ANNUAL MEETING TO BE HELD IN WASHINGTON, D. C., APRIL 27-30, 1960—Last-minute attention is called to the previous announcements in the *Transactions* concerning the Forty-First Annual Meeting to be held in Washington, D. C., April 27-30, 1960. Note that earlier calls to this meeting indicated the beginning date as April 28, but it now appears that sessions in general will begin on Wednesday, the 27th. Two programs definitely planned to start on the 27th are: (1) the program on Solar Upper Atmosphere Relations, which will be part of the National Academy of Sciences program, held jointly with the IGY group, and (2) the sessions in Meteorology, being held jointly with the American Meteorological Society. Because of the magnitude of the meeting in prospect, it appears that other programs will also be held on the 27th. It is anticipated that programs will be mailed to all members about April 10.

Information regarding lodging accommodations appears in the December 1959 issue of the *Transactions*, pages 373 and 374. Bear in mind that in general advance bookings require a deposit, and bookings on which deposits have not been made are usually canceled two weeks in advance of the meeting. Thus during the interval immediately preceding the meeting there is a fairly good chance of making a reservation. However, even though no advance arrangements for quarters have been made, it is usually possible to secure these upon arrival in Washington through the Housing Committee of the Washington Board of Trade (1616 K Street, N.W., Washington, D. C.), telephone REpublic 7-2600 or STerling 3-3535, but they may find it necessary to direct you to a tourist home.

• TWELFTH GENERAL ASSEMBLY OF THE IUGG—In accordance with earlier announcements, the Twelfth General Assembly of the International Union of Geodesy and Geophysics will be held in Helsinki, Finland, July 25 to August 6, 1960. Citizens of the United States who plan to attend should get into touch at once with the office of AGU in order that they may be appropriately accredited to the meeting. Nationals of other countries in residence in the United States who will not attend as delegates of their own countries may attend as guests of the U. S. National Committee upon making appropriate arrangements with the office of AGU. Plans for the seven

Associations and meetings of the Union as a whole are quite complete, and Circulars 1 and 2 from the Finnish National Committee concerning reservations and registration have been mailed to those of whom the AGU office is now aware that plan to attend. Earlier notes regarding the meeting appear under Special Announcements in the March, June, and December issues of the *Transactions* of 1959, and under Union, Section, and Committee Activities in the September issue, pp. 262-267.

Regarding the program of the Association of Meteorology and Atmospheric Physics, word has recently come of the following symposia:

Dynamical Processes in the Atmosphere, being organized by Philip D. Thompson (presently at the Institute of Meteorology, University of Stockholm, Lindhagensgatan 124, Stockholm K. Sweden), in consultation with R. D. Sutcliffe, Secretary of the Association (Meteorological Office, Victory House, Kingsway, London W.C. 2, England).

Aurorae, being organized by the International Association of Geomagnetism and Aeronomy.

Results from Rockets and Satellites, being organized by the General Secretary of the IUGG, G. Laclavère (53, Avenue de Breteuil, Paris 7, France).

Atmospheric Electricity, being organized jointly by the Associations of Meteorology and Atmospheric Physics and of Geomagnetism and Aeronomy by H. Koenigsfeld (rue de l'Etat Tiers 17, Liège, Belgium).

Tsunamis and Storm Surges, being organized by the International Association of Seismology and Physics of the Earth's Interior, in collaboration with the Association of Physical Oceanography and the Association of Meteorology and Atmospheric Physics.

Low Water Supply and Periods of Drought, being organized by the Association of Scientific Hydrology.

Atmospheric Chemistry and Radioactivity, being organized by W. Bleeker (Netherlands Meteorological Institute, DeBilt, The Netherlands) and C. E. Junge (Geophysics Research Directorate Air Force Cambridge Research Center, Bedford, Massachusetts).

The High Atmosphere, being organized jointly by the Association of Meteorology and Atmospheric Physics and the Association of Geomagnetism and Aeronomy by E. Vassy (Faculté des Sciences, 1 quai Branly, Paris VII, France).

Attention is also called to the Symposium on Aeronomy to be held in Copenhagen, July 19-22, 1960, by the Association of Geomagnetism and Aeronomy, details of which can be secured from M. Nicolet (30 Avenue den Doorn, Brussels 18, Belgium).

In addition, the organizers of the meeting in Meteorology will include a number of papers from

especially invited speakers, but any individual is free to request a place on the program, and the organizers will do everything possible to meet such requests within the restrictions of the available time. Titles and abstracts are now overdue, but persons interested should send communications to the Secretary of the International Association of Meteorology and Atmospheric Physics, R. C. Sutcliffe, at the address noted above. Copies of correspondence, including abstract and title, should be sent to the Chairman of the U. S. Committee on International Participation of the Section of Meteorology, AGU, namely, H. R. Byers

(Department of Meteorology, University of Chicago, Chicago 37, Illinois).

Note added in page proof—The Second Circular has just arrived from the Finnish Committee on Arrangements. Copies have been mailed to those who have signified plans to attend the XII General Assembly. The circular includes forms for registration and for reservations, and contains outlines of the programs, and word regarding lodging arrangements, excursions, and other information useful to participants. It is still not too late to make plans to attend, and a few copies of the circular are still available, reserved for those who plan to attend.



IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation—1959 as related primarily to United States programs

Radiation Studies on the South Polar Snowfield

This report is based on material prepared by Kirby J. Hanson, of the US Weather Bureau. A more detailed account will appear in the Journal of Geophysical Research, March 1960.

To an observer at the IGY Amundsen-Scott South Pole Station, the polar plateau appears flat and unbroken as far as the eye can see in all directions. The sun is above the horizon continuously for six months, and the snow-surface temperature remains below 0°C throughout the year. All of these factors make the geographic South Pole a most suitable place to measure the solar and terrestrial radiation fluxes, and associated energy exchanges, peculiar to a high-altitude (9280 feet above mean sea level), high-latitude snowfield. The first such observations at the South Pole were made during the IGY. This report presents preliminary results of these studies.

The IGY radiation program at the South Pole Station was established by E. C. Flowers during the 1956–57 season. It was continued in 1957–58 by Kirby J. Hanson with the assistance of D. M. Baulch and A. E. Jorgensen. Harry Wexler and T. H. McDonald contributed helpful suggestions and advice. All of the above are personnel of the US Weather Bureau.

Instrumentation

The radiation instruments were located about 300 yards from the station. Direct solar radiation was measured with an Eppley normal-incidence pyrheliometer. This instrument, mounted about one and one-

half meters above the snow surface, was able to "follow the sun" continuously during the six-month south polar day. However, since the sun itself occupies only a small portion of the total area that the instrument "sees," cloudiness increases the ratio of diffuse sky to direct solar radiation; thus, the error in measuring direct solar radiation also increases. For this reason, measurements of direct solar radiation were made during clear sky conditions only.

Total global radiation, or the total radiation (short-wave) falling on a unit area of horizontal surface, was measured by an Eppley horizontal-incidence pyrheliometer, or pyranometer, about two meters above the snow surface. In order to measure the total global radiation reflected from the snow surface, an identical Eppley horizontal-incidence pyrheliometer was inverted and mounted five meters above the snow.

Also used were the Beckman and Whitely total hemispherical radiometer (effective pyranometer) and net exchange radiometer (radiation balancemeter). The total hemispherical radiometer measures the total global radiation plus atmospheric (long-wave) radiation downward. This instrument is unaffected by the type of surface beneath it, since it only measures the radiation from the hemisphere above. The net exchange radiometer on the other hand is affected by the snow-surface temperature and albedo (reflectivity) since it measures the shortwave radiation balance (incoming-outgoing) plus the long-wave balance (incoming-outgoing).

Radiation Observations

Solar Radiation: Incoming solar radiation has two components: diffuse sky and direct.

Figure 1 shows the relationship between

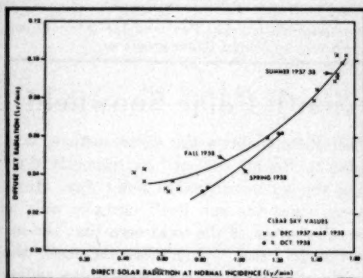


Fig. 1. Plot of Diffuse Sky Radiation Against Direct Solar Radiation at Normal Incidence for Clear-Sky Conditions at Amundsen-Scott Station.

normal-incidence direct solar radiation and diffuse sky radiation at the South Pole. Apparently, there is less scattering of the solar beam in spring than in fall. By converting direct normal-incidence solar radiation to horizontal-incidence radiation the mean diffuse, clear-sky radiation can be shown as a function of the direct solar radiation on a horizontal surface (Fig. 2).

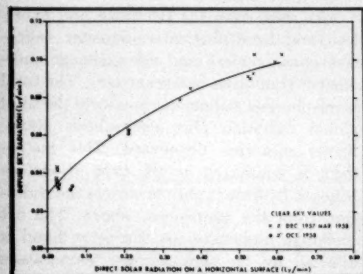


Fig. 2. Plot of Diffuse Sky Radiation Against Direct Solar Radiation on a Horizontal Surface for Clear-Sky Conditions at Amundsen-Scott Station.

This relationship gives a good estimate (0.03 ly/min) of the diffuse, clear-sky radiation at sundown, i.e., when the direct solar radiation is zero. (One langley, ly, is equal to one calorie per square centimeter.)

At the South Pole, diffuse sky radiation is about 14% of the total global radiation in mid-summer. G. H. Liljequist, some years ago, found the minimum value of the ratio of diffuse sky to total global radiation to be 17% at Maudheim (71°S) on the coast of Antarctica. On the Greenland Ice Cap near 78°N, M. Diamond and R. W. Gerdel found a ratio of 19%.

Comparisons and Relationships of Radiation Measurements

In Figure 3, direct solar radiation at normal incidence (curve 1), the vertical component of direct solar radiation (curve 2), total global radiation (curve 3), dif-

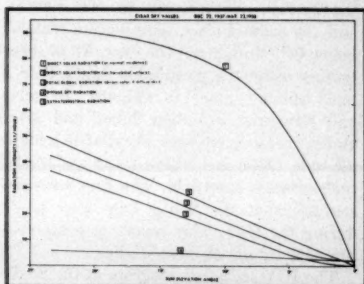


Fig. 3. Solar Radiation, Amundsen-Scott Station, December 22, 1957-March 22, 1958 (clear-sky values).

fuse sky radiation (curve 4), and extraterrestrial radiation, i.e., the solar radiation falling on a horizontal surface outside the earth's atmosphere (curve 5), are plotted against various sun elevation angles. Many applications and comparisons of these radiative fluxes can be made; a few are discussed below.

Atmospheric Transmission of Solar Radiation: "Atmospheric transmission coefficient"

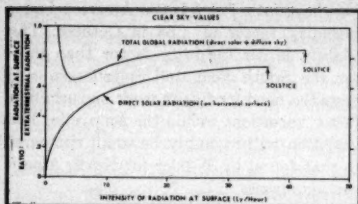


Fig. 4. Transmission Coefficient Curves for Direct Solar and Total Global Radiation, Amundsen-Scott Station, Summer 1957-58 (clear-sky values).

cient" is here defined as the ratio of radiation observed at the surface to extraterrestrial radiation. Figure 4 shows the transmission coefficients for direct solar and total global radiation as a function of the intensity of their respective fluxes observed at the surface. It can be seen that the transmission coefficient for the direct solar beam is approximately .75 near the summer solstice, decreasing to zero at sundown. This large transmission coefficient near solstice indicates low atmospheric turbidity. The transmission coefficient for the Pole Station at the summer solstice is approximately the same as that found by H. Kimball for the same relative air mass at Mt. Whitney, California, approximately 5250 feet higher than the Pole Station. Kimball also found equal transmission coefficients for Spitzbergen and Mt. Wilson, California. The difference in their altitudes is approximately 5600 feet.

The total global radiation curve indicates what percentage of the radiation available per unit area at the top of the atmosphere will finally reach an equivalent area on the surface, regardless of the manner in which it arrives—diffusely scattered, reflected, or direct. Total global radiation is about 85% of the extraterrestrial radiation with clear skies in mid-summer.

Depletion of solar radiation, either by intervening cloudiness or by clear air, is smaller in polar regions than in middle latitudes. Moreover, in polar regions, cloud

conditions may arise in which the diffuse sky component of radiation on a particular unit area of the surface may increase while there is no depletion of the direct solar beam. The result is a sizeable increase in total global radiation—large enough, at times, so that the total global radiation may exceed the extraterrestrial radiation (see Fig. 5). Total global radiation also exceeds extraterrestrial radiation at sundown.

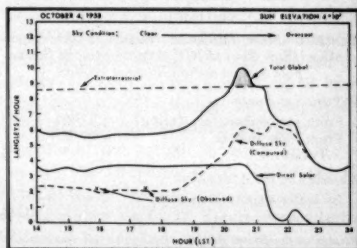


Fig. 5. Anomalous Total Global Radiation, Amundsen-Scott Station, October 4, 1958.

Atmospheric Solar Radiation Balance:

The curves in Figure 4 may be used to estimate directly the solar radiation balance of the south polar atmosphere. If this is done for a particular time (in this case the summer solstice), and acceptable values for atmospheric scattering and absorption by water vapor, dust, and dry air are used, the depletion of extraterrestrial radiation is accomplished as follows: 74% is reflected back to space; 13% is absorbed by water vapor, dust, and dry air (the latter includes O_2 , O_3 , and CO_2); 13% is absorbed by the snow surface. (See Table 1, next page, for a more complete break-down of the south polar radiation balance.)

Even though the polar plateau receives more extraterrestrial radiation than is possible anywhere else on earth, only a small percentage is finally absorbed by the snow surface—13% (or 148 ly./day). By comparison, Sigmund Fritz, in 1951, found that

in middle latitudes during cloudless conditions about 80% of the daily energy entering the outer atmosphere reaches the ground. Assuming an albedo of roughly 10%, except in snow-covered areas, he concludes that about 72% of this energy, or about 450 ly/day, is absorbed by the earth's surface. This value is about 3 times as large as that found at the South Pole, even when maximum insolation is being received and the day is twice as long as a middle-latitude day.

TABLE 1—*Solar Radiation Balance in the Atmosphere (Clear Sky) at IGY Amundsen-Scott South Pole Station during Summer Solstice*

<i>Reflection to Space</i>		
From atmosphere (scattering)	= 17%*	
From snow surface	= 57%	
Total	=	74%
<i>Absorbed by the Atmosphere</i>		
By water vapor, dust, and dry air	=	13%
<i>Fluxes at the Snow Surface</i>		
Diffuse sky radiation	= 13%	
Direct solar radiation	= 78%	
Total global	= 91%	
Reflected global	= 78%	
TG-RG	= 13%	
<i>Absorbed by the Snow Surface</i>	=	13%
Total	=	100%

* All values represent approximate percentages of extraterrestrial radiation.

Turbidity Factor: The turbidity factor is a simple index of the dust and water-vapor content of the atmosphere, originally expressed as the number of clean, dry atmospheres needed to produce the attenuation of solar radiation found in a real atmosphere containing water vapor and dust. By definition, the turbidity factor can never be less than 1.0.

A turbidity factor of 1.40 was found for the South Pole Station during the summer. Direct comparison with other stations at or near sea level can be made. Kimball found a turbidity factor of 1.41 for Spitzbergen in summer, almost exactly the same as that

for the South Pole. Little America had a turbidity factor of 1.68 in October. This slightly larger turbidity factor than those for the South Pole and Spitzbergen suggests the need for future work on turbidity-factor variations within the Antarctic. This variation will probably be small compared to that found by Wexler for North American air masses.

Albedo: In terms of its albedo, the surface of the polar plateau may be considered a "new" snow surface, since it is not subjected to melting or contamination, although undergoing occasional drifting. The albedo percentages for the six summer months are as follows: the first two sunlit months (referred to as "spring" for purposes of comparison), 77% when clear, 84% when cloudy; the second two ("summer"), 74-83% when clear, 80-88% when cloudy; and the last two ("fall"), 87% when clear, 93% when cloudy.

The 10% difference between spring and fall may be attributed to the changing character of the snow surface. In spring, the surface is rough owing to wind action during the winter night, when wind speed averages about 15 knots. In middle or late summer, however, increasing precipitation and decreasing wind velocity (to about 8 knots) tend to smooth the surface so that by fall little or no trace remains of the wind-induced surface patterns of the previous winter.

Thus, the albedo is near 80% in the spring, remaining constant through early summer. Then, as the surface becomes smoother, albedo increases to about 85% in mid-summer, and finally averages about 90% in the fall. Cloudy-day albedos appear to be 5-7% higher than those for clear days.

On rare occasions during the summer, the sky may become overcast with a low, uniform cloud cover (but not so low as to restrict surface visibility). On such occasions, multiple reflection of sunlight between the cloud base and the snow surface

diffuses the light so that the drifts are illuminated equally on all sides, causing all shadows to disappear and surface features, including the horizon, to become indistinguishable. This condition is commonly known as a "whiteout."

On other days, however, the sky may be overcast with a *non-uniform* cloud base, and no whiteout is present. Snow-surface albedos on these two types of overcast days are nearly identical, averaging about 1% higher during whiteout conditions.

"Warm" Cloud Effect: During the World Meteorological Interval (WMI) of June 15-24, 1958, the sky remained clear continuously for eight days and the snow-surface temperature reached a low of -104°F . The polar plateau was in continuous darkness during the period and, therefore, no solar radiation was received. Hence, the interval was ideal for studying, under conditions of extreme cold, the incoming flux of long-wave radiation from the atmosphere only.

During the first eight days, the hemispheric radiation averaged about 5 ly/hr—a typical value under conditions of clear skies, low atmospheric moisture content, and low surface temperatures. With an increase in cloudiness, precipitation, and surface wind on June 23, there was a marked increase in both surface temperature and hemispheric radiation.

The short-period variations of hemispheric radiation and snow-surface temperature were about equal during clear periods, but in cloudy weather the hemispheric-radiation variations were considerably larger than those of snow-surface temperature. This suggests that hemispheric radiation does not exhibit a singular control over snow-surface temperature. Two sensible heat fluxes exhibit a partial control, however—the flux of eddy diffusion and the subsurface heat flux.

Sensible Heat and Radiant Energy Fluxes: During the 18-month IGY period, temperatures at the South Pole (at about

two meters above the ground) fell below -100°F on five separate days. These minima were approximately -100° , -101° , and, on three days, -102°F . The minimum temperature of -102° is apparently a "favored" equilibrium temperature for the present circulation-temperature regime at the geographic South Pole.

Examination of a period when this temperature extreme occurred shows how the radiant-energy and sensible-heat fluxes contribute toward an energy balance at the snow-atmosphere interface. A period in mid-September when the 2-meter temperature reached -101.7°F was selected for study (Fig. 6). With a wind of 15 knots and scattered cloudiness, the temperature had dropped to its minimum value by the middle of the period. Increased cloudiness raised the temperature to -90°F by the end of the period.

As shown by C, in Figure 6, net radiation, or the radiant energy balance at the snow surface, represents a net loss of energy at the snow surface during this mid-September period. The radiant energy balance does not exhibit a singular control over snow-surface temperature, however, since the sensible heat fluxes—(D) eddy diffusion (or turbulent transport of heat from air to surface) and (E) subsurface flux (or heat conducted upward from the snow)—also contribute to the surface energy balance.

During the first of the four periods, C represents an energy loss and fluxes D and E represent gains. If no other energy exchange processes were operating at the surface, one would expect C to equal D plus E. However, C is found to be slightly larger than D plus E; hence, there is a small negative remainder (-0.007 ly/min). This remainder is shown as F (net flux), and during the first period could have resulted from sublimation of the surface at the rate of 0.15 mm of water/cm²/day. During the next two periods, F was zero, indicating that the net sublimation was about zero. During the last period, F was

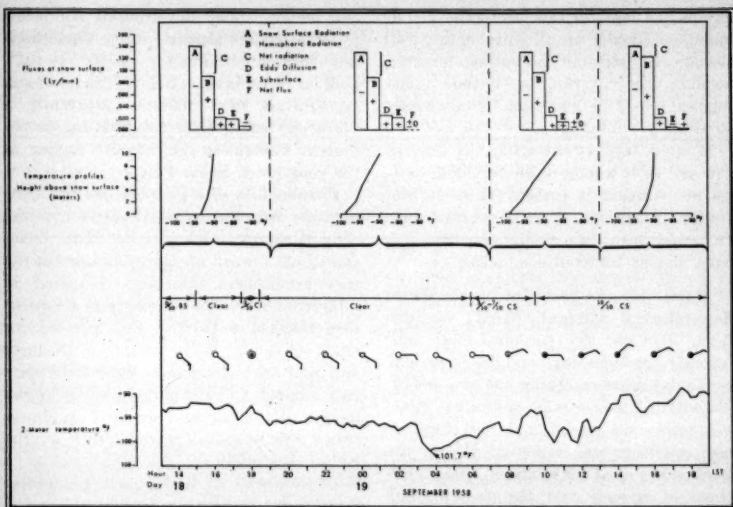


Fig. 6. Surface Meteorological Conditions and Radiant and Sensible Heat Fluxes at Amundsen-Scott Station, September 18-19, 1958.

slightly positive ($+0.002$ ly/min) and indicates deposition at the rate of 0.04 mm of water/cm²/day.

The four consecutive balance observations shown in Figure 6 permit study of the change in the fluxes with time, bearing in mind that the snow-surface radiation is a function of snow-surface temperature only. Hemispheric radiation was relatively small (0.09 ly/min) during the first three periods, but increased (to almost 0.12 ly/min) as the sky became overcast. As a result, the net radiation, ranging from -0.04 to -0.05 ly/min during the clear, cold period, approached zero as the value of the warm cloud radiation approached that of the snow-surface radiation.

It can now be seen how the sensible heat fluxes make up the loss in radiant energy. During the first two periods, the two sensible heat fluxes were nearly equal in magnitude; however, as the temperature began

to increase, the subsurface heat flux decreased to about half that owing to eddy diffusion. By the last period, the air temperature had increased such that the net flux of heat was *into* the snow surface rather than *out of* it. The eddy-diffusion flux was still large, since no decrease in surface wind was observed. In fact, it was larger than the net loss of radiant energy (C), and so accounts for the flux into the snow (E).

The above situation may be quite typical of the warming on the polar plateau when relatively warm clouds (up to 50°F warmer than the snow surface), acting as "black body" radiators, are introduced after a clear, cold period. This warm-cloud effect occasionally causes net radiation to approach, and sometimes exceed, zero. When net radiation is zero, the heat conducted from the atmosphere to the snow surface is then conducted downward into the snow. Thus, it is seen that the rapid

warming of the south polar plateau by warm cloud radiation is aided by the molecular and eddy conduction of heat from the air.

Conclusions

F. Loewe estimated the net radiation loss for the Antarctic inland ice as 100 ly/day. At Port Martin on the coast of Antarctica Loewe found in 1951-52 a net loss of 20 ly/day, almost the same as the net loss of 25 ly/day found by Liljequist at Maudheim, another coastal station, in 1949-52. For the IGY period, the radiation

loss at the South Pole is estimated at 35 ly/day, or less than half that estimated by Loewe for inland areas.

The south polar plateau is a radiative cold source. The estimated magnitude of the heat loss is large enough to cool the first 10 meters of snow by about 100°C per year, if radiation alone controlled the energy balance at the surface. Observations have shown that the annual temperature variation at a depth of 10 meters is less than 1°C; therefore, it is apparent that vertical and horizontal heat transport represent an energy gain nearly equal to the net radiation loss.

Intensity Variations of Primary Cosmic-Ray Components

The following report is based on material supplied by Peter Meyer, of the Enrico Fermi Institute for Nuclear Studies, University of Chicago. A more detailed account appeared in The Physical Review, September 15, 1959.

Two series of high-altitude IGY balloon flights were made by University of Chicago investigators in 1957 and 1958 to study short-term intensity variations of the proton (H^+) and alpha-particle (He^{++}) components of the primary cosmic-ray flux, and their interrelationships. The experiment sought to explain the changes observed in total cosmic-ray flux by obtaining more information on intensity variations of these different components of the primaries. (Protons make up approximately 86% of primary cosmic rays, alpha particles 13%, and still heavier nuclei 1%. The secondary flux, formed by interaction of primaries with atmospheric particles, includes secondary protons and nucleons, pi

mesons [both charged and neutral], and heavier mesons.)

Bulletin No. 15 presented the results of two of the earlier flights made as part of this experiment. This report reviews the experimental techniques, results, and conclusions of the entire series. The studies were directed by Peter Meyer. Other University of Chicago personnel helped in building and maintaining the equipment, in the launching, and in computation and data processing.

Variations in the total cosmic-ray intensity have been observed for many years, mainly by permanently installed cosmic-ray monitors at ground stations capable of recording intensities over long periods of time. More recently, these ground observations have been complemented by measurements with instruments carried by aircraft, balloons, rockets, satellites and space probes.

Past studies have shown that most variations of cosmic-ray intensity occur in the

primary flux and do not result from local influences such as geomagnetic or meteorologic effects. It has also been demonstrated that the mechanisms giving rise to such variations must be solar-controlled and must operate within or near the solar system. Although extensive studies have been carried out to account for the observed phenomena, no single complete explanation has as yet been found. However, a rather close correlation was noted between changes in the alpha-particle and proton intensities, and it was concluded that the same mechanism is responsible for the intensity modulation of both.

Detailed comparisons of the variations in alpha-particle and proton fluxes have special value in studies of primary cosmic-ray variations. If, for example, the total flux of low-energy primaries is of galactic origin and the intensity modulation results from disordered magnetic fields within the solar system, very similar changes for each rigidity interval (see below) of both protons and alpha particles would be expected. On the other hand, if solar production of particles with cosmic-ray energies plays a more important role than is generally assumed, variations in the ratio of the alpha-particle flux to the proton flux are likely to occur.

The Experiment

The technique used involved a combination of scintillation and Cerenkov counters, allowing discrimination between alpha particles and protons. This technique, first described by F. B. McDonald, is capable of measuring the alpha-particle flux over an appreciable energy range. Using lucite (a transparent synthetic resin) with an index of refraction of 1.5 in the Cerenkov counter, alpha particles with energies down to 450 million electron volts per nucleon (or 1800 mev/particle) are easily distinguished from low-energy protons.

Since the investigation was concerned pri-

marily with short-term variations—the 27-day variation, the sudden Forbush-type intensity decreases accompanying magnetic storms, and, possibly, 24-hour variations—the ground-level neutron monitor at Chicago was used to choose appropriate times to make observations. Balloons carrying the instrumentation described were sent to altitudes of about 100,000 feet (near the “top of the atmosphere” for cosmic-ray effects) in two series of measurements at high geomagnetic latitudes. A total of seven successful flights were made, of which five are included in the present analysis. Of the first series, flown from Prince Albert, Saskatchewan, Canada, flights of August 16, August 30, and September 16, 1957, are discussed; of the second series, from Neepawa, Manitoba, Canada, flights made on July 12 and 22, 1958, are analyzed. Prince Albert is at geographic latitude $53^{\circ} 13' N$, $105^{\circ} 41' W$, and Neepawa is at $50^{\circ} 16' N$, $99^{\circ} 27' W$. The balloons remained at peak altitude for about 8 hours during the 1957 flights and for about 20 hours in the 1958 flights.

The geomagnetic rigidity cut-offs for Prince Albert and Neepawa are 0.6 and 0.7 billion electron volts, respectively. (Magnetic rigidity = momentum/charge, and measures a particle's resistance to deflection by a magnetic field.) These rigidity cutoffs are well below the lower rigidities of the spectrum of primary cosmic rays, and it may be expected that the small changes in latitude during the flights would not noticeably influence the flux measurements. The cut-off for any geomagnetic latitude represents the lowest rigidity normally capable of penetrating the geomagnetic field at that latitude: high-energy particles, with correspondingly high rigidities, can penetrate the earth's field at the equator, but very low energy particles can penetrate only in the vicinity of the magnetic poles.

The 1957 observation period showed the greatest cosmic-ray intensity changes for the entire year. About September 1, in particular, solar activity was very high, resulting in large intensity variations.

TABLE 2

Date	Climax Neutron Monitor Intensity	Average Pressure During Flight (mm Hg)	Total Number of Protons Counted in Flight	Proton Flux ¹ Corrected for 13.5 g/cm ²	Total Number of α -Particles Counted in Flight ($E > 530$ Mev/nucleon)	α -Particle Flux ¹ Corrected for 13.5 g/cm ² and Background ($E > 530$ Mev/nucleon)	α -Particle Flux at the Top of the Atmosphere ($E > 560$ Mev/ nucleon)
Aug. 16, '57	2841 $\pm$ 1%	11.3	41,940	1910 $\pm$ 2%	2,275	103.0 $\pm$ 4%	136.4 $\pm$ 9%
Aug. 30, '57	2480 $\pm$ 1%	10.2	48,546	1662 $\pm$ 2%	2,265	94.0 $\pm$ 4%	124.4 $\pm$ 9%
Sept. 16, '57	2780 $\pm$ 1%	10.2	51,424	1921 $\pm$ 2%	3,224	115.1 $\pm$ 4%	153.9 $\pm$ 9%
July 12, '58	2709 $\pm$ 1%	9.4	75,828	1627 $\pm$ 2%	5,094	103.7 $\pm$ 3%	138.0 $\pm$ 8%
July 22, '58	2694 $\pm$ 1%	9.0	80,701	1588 $\pm$ 2%	5,836	105.2 $\pm$ 3%	140.1 $\pm$ 8%

¹ All flux figures in particles per square meter per steradian (unit solid angle) per second

Results

Values of the proton and alpha-particle fluxes for the five selected balloon flights were compared with the total cosmic-ray intensity measured with a ground-based neutron monitor at Climax, Colorado (see Table 2). All alpha-particle data were normalized to an altitude corresponding to an atmospheric pressure of 13.5 gm/cm² (about 96,500 feet), and corrections were made for the general radiation background in the alpha-particle region. A similar procedure was used to correct proton-flux values to the same level.

Alpha-Particle and Proton Flux Changes on August 30, 1957: Measurements of the alpha-particle and proton fluxes were made

before, during, and after a large Forbush-type intensity decrease on August 30, 1957. (Forbush decreases frequently accompany geomagnetic storms, following a solar flare by about a day; these decreases are thought to be caused by the cloud of ionized gas hurled outward by the flare.)

Using for reference the values obtained on August 16, about two weeks before the Forbush decrease, Table 3 compares the changes in total intensity as recorded at three neutron-monitor stations, with balloon data on proton intensity, and intensity of alpha particles with energies greater than 530 mev/nucleon at the altitude of observation. It can be seen that, during this period, relatively similar changes occurred in the average intensities of both protons and al-

TABLE 3

Date	Balloon Data		Neutron Monitor Station Data		
	Proton Flux % Change	α -Particle Flux % Change $E > 530$ Mev/nucleon	Sulphur Mountain $R = 0.98$ BV	Climax $R = 2.71$ BV	Sac. Peak $R = 4.7$ BV
Aug. 16, '57	0	0	0%	0%	0%
Aug. 30, '57	-13.0 $\pm$ 2	-9 $\pm$ 4	-12.4%	-12.7%	-7.9%
Sept. 16, '57	+0.6 $\pm$ 2	+12 $\pm$ 4	-4.1%	-2.1%	—
July 12, '58	-14.8 $\pm$ 2	+1 $\pm$ 4	-7.3%	-4.8%	-1.6%
July 22, '58	-16.8 $\pm$ 2	+2 $\pm$ 4	-6.6%	-5.2%	-2.8%

pha particles (within the accuracy range of the experiment). During the two weeks following the decrease, the intensities of both components returned to high values, with the alpha-particle increase substantially exceeding that of the protons. When the relative intensity changes observed at the various neutron-monitor stations are compared, it appears that for particles with rigidities of less than 4 bev very little dependence on rigidity existed in this event.

To investigate the possible rigidity dependence of the alpha-particle variation, the flux was divided into two intervals: the first included alpha particles with energies between 450 and 960 mev/nucleon and the second included those with energies exceeding 960 mev/nucleon. Table 4 lists the

TABLE 4

Date	α -Particle Flux 450-960	α -Particle Flux >960
	Mev/nucleon ¹	Mev/nucleon ¹
Aug. 16, 1957	33 $\pm$ 6%	85 $\pm$ 5%
Aug. 30, 1957	31 $\pm$ 6%	72 $\pm$ 5%
Sept. 16, 1957	38 $\pm$ 6%	87 $\pm$ 5%
July 12, 1958	37.6 $\pm$ 5%	77.5 $\pm$ 4%
July 22, 1958	35.1 $\pm$ 5%	81.8 $\pm$ 4%

¹ Corrected for 13.5 g/cm² and shown in particles per square meter per steradian (solid unit angle) per second

alpha-particle fluxes within these energy intervals for the five flights. There appears to be no evidence for a strong dependence on either energy or rigidity. The investigators therefore conclude that, within the total energy range covered by this experiment, a common modulation mechanism operated on both the alpha-particle and the proton fluxes during the large Forbush decrease of August 30, 1957.

The rigidity relationship of this particular event differs strikingly from that of cosmic-ray variations related to the 11-year solar cycle, adding to increasing evidence that the mechanisms responsible for these two types of intensity variations are

not closely related. The lack of dependence on rigidity of the Forbush decrease can be explained on the basis of modulation of the flux by disordered magnetic fields. It appears that the scale of the disordering is equal to the Larmor radius (the radius of deflection of a particle in a magnetic field) at the energy below which the lack of dependence on rigidity occurs. Aircraft measurements by J. A. Simpson, made before, during, and after a Forbush decrease on August 18, 1951, also showed this lack of dependence on rigidity in the same rigidity interval. (The present experiment was not capable of discriminating between energy dependence and rigidity dependence of the variations measured.)

Intensity and Energy-Spectrum Changes Between 1957 and 1958

Noticeable changes occurred in the intensity and energy spectrum of primary cosmic rays in the interval between the two series of balloon flights. In Table 3, decreases in neutron intensity of about 7% at Sulphur Mountain, Canada, and about 5% at Climax, Colorado, are evident between 1957 and 1958. For the same interval, a drop of about 15% in proton intensity can be seen. (K. B. Fenton reports that a decrease in intensity comparable to the proton decrease was observed by balloon-borne neutron equipment at high altitude and latitude during this period.)

A strong dependence on rigidity is indicated by the above changes, in contrast to the lack of rigidity dependence during the Forbush decrease of late August and early September 1957. Moreover, aircraft measurements have shown that the rigidity cut-off of the primary cosmic-ray spectrum changed from low to higher values between summer 1956 and early 1958.

These changes in the low-energy end of the cosmic-ray spectrum and in rigidity dependence are in accord with the 11-year cosmic-ray-intensity cycle. (Observations over the past few decades have shown that cosmic-ray intensity varies inversely with

the 11-year sunspot cycle: when sunspot activity reaches a peak in the cycle, cosmic-ray intensity falls off; when solar activity is at a minimum, cosmic-ray intensity increases.)

Decreases comparable to those described for protons and neutrons were not found during the 1957-1958 interval in the flux of primary alpha particles with energies greater than 530 mev/nucleon. This flux remained virtually unchanged. Hence, the ratio of the proton flux to the alpha-particle flux, at a height level of 13.5 gm/cm², decreased from an average of 17.6:1 in 1957 to 15.4:1 in 1958.

However, when the alpha-particle flux was divided into two energy levels—particles with energies of 450-960 mev/nucleon and particles with energies greater than 960 mev/nucleon (see Table 4)—it was found that intensity decreased in the higher-energy group, while the lower-energy flux increased. (Statistical accuracy of the two-energy-level study is lower than that of the flux measurement of particles with energies greater than 530 mev/nucleon.) The behavior of the alpha-particle flux at the two energy levels is exactly opposite that to be expected on the basis of the proton-flux data.

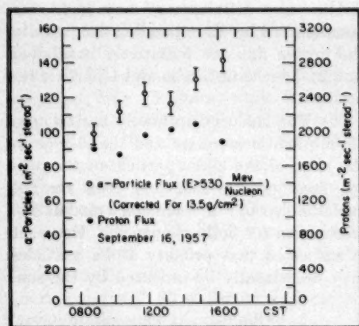


Fig. 7. Increase in Alpha-Particle Flux With Time.

Rapid Variations in the Alpha-Particle Flux

To study in detail the primary cosmic-ray flux as a function of time, the flight periods were divided into 90-minute intervals. During all of the 1957 measurements, an increase in the alpha-particle flux with time was apparent, but it was not accompanied by a similar variation in proton flux. This effect was most noticeable in the September 16 measurements (see Fig. 7.) As all of the 1957 flights were launched in the early morning hours, they represent about the same periods of local time.

The alpha-particle increase was observed not only for particles with energies exceeding 530 mev/nucleon, but also, with comparable amplitude, in both the 450-960 mev/nucleon energy level and in the level including particles with energies above 960 mev/nucleon. (The total cosmic-ray intensity was measured independently in another experiment by F. Jones and K. Yates. Using a vertical geiger-counter telescope, they found that the time relationship of the total intensity was the same as that of the proton flux.)

A similar increase in the alpha-particle flux without a corresponding increase in protons was also observed on March 13, 1956, by F. B. McDonald. This earlier measurement, like those of the present experiment, also was made during a large Forbush decrease in total cosmic-ray intensity accompanying a period of enhanced solar activity.

This increase in alpha-particle intensity while the proton flux remains relatively unchanged is tentatively attributed by the University of Chicago investigators to a 24-hour variation in the alpha-particle flux or to an anisotropy—a difference in the properties of the flux with direction. Further studies are planned to test this hypothesis.

In order to investigate this effect in greater detail, the 1958 flights, during a period when no enhancement of solar activity took place, remained at peak altitude for about 20 hours. However, no similar

independent increase in alpha-particle intensity was observed.

Absolute Flux of Primary Alpha Particles

Owing to the greater length of time of each measurement and to the wider angle of coverage of the equipment, the total number of alpha particles counted during each flight of the present investigation is substantially higher than in any previous experiment. It was therefore thought worthwhile to use this data to determine the absolute flux of primary alpha particles at the top of the atmosphere—in particles per square meter per steradian, or unit solid angle, per second.

The results of these computations are shown in the last column of Table 2, which gives the flux of all primary alpha particles with energies greater than 560 mev/nucleon after first accounting for an energy loss of 30 mev/nucleon during the particles' traversal of the residual atmosphere and the measuring equipment.

Summary and Conclusions

Two series of measurements of the proton and alpha-particle fluxes of the primary cosmic radiation were made in 1957 and 1958 using balloon-borne scintillation and Cerenkov counters. On one of the flight series, measurements were obtained before, during, and after a large Forbush-type intensity decrease which occurred on August 30, 1957. The following conclusions were arrived at by the investigators after analysis of the flight data:

(1) Since both the proton and alpha-particle fluxes showed the same relative variation during the Forbush decrease, it is postulated that a common modulation mechanism operated in the same way on both components. No energy dependence

was found for the intensity variations associated with this event.

(2) The relative proton-intensity change at altitude was about the same as the change observed by neutron monitors in Colorado and Canada; hence, virtually no rigidity dependence was noticeable in this Forbush decrease up to a rigidity of 4 bev.

(3) Comparison was made of the proton intensity decrease of about 15% at high altitude and latitude between measurement days in 1957 and 1958 with decreases of 7% and 5%, respectively, at neutron-monitor stations in Canada and Colorado in the same period; a change in the low-energy end of the primary proton spectrum was indicated. This change is believed associated with the primary cosmic-ray variation related to the 11-year solar-activity cycle.

(4) Unlike the proton flux, the flux of alpha particles with energies greater than 530 mev/nucleon remained unchanged between 1957 and 1958. However, division of the alpha-particle flux into a higher and a lower energy group showed (with less certain statistical accuracy) a decrease in intensity of the high-energy group and an increase in the low-energy group. This result is opposite that to be expected from the proton data.

(5) Increases in alpha-particle flux for several hours during 1957 daylight flights (while solar activity was very high) not accompanied by corresponding decreases in the proton flux are tentatively attributed to a 24-hour variation in alpha-particle intensity.

(6) The independent hourly variation in alpha-particle intensity and the change in the ratio of the alpha-particle to the proton flux between 1957 and 1958 are not explainable by a common modulation mechanism for both components. Hence, it is suspected that primary alpha particles may occasionally be produced by the sun.

Solar Flares, Geomagnetic Disturbances, and WWA Decisions, Third Quarter 1959

This report is one of a series issued periodically throughout the IGY and IGC-59. See Bulletin No. 28 and the Indexes to Bulletins 1-24, published in Bulletins 12 and 24, for earlier reports in this series.

During the third quarter of 1959 (July 1—September 30), a general increase in geomagnetic activity was observed, as shown by the greater frequency, severity, and duration of disturbances. The most severe geomagnetic storm began on July 15 (see list below) and produced an A-index unsurpassed by that of any disturbance on record at WWA—the World Warning Agency. (The A-index is a daily magnetic-activity index which averages, on a linear scale ranging from 0 to 400, the eight daily 3-hourly indices; the 3-hourly indices are defined as one-half the average range, in gammas, of the most disturbed of the three components of geomagnetic force—vertical, horizontal, and declination—at standard geomagnetic stations.)

This severe storm of mid-July was associated with a great flare observed in an extremely active region in the vicinity of the sun's central meridian. Other major flares produced by this solar region were followed by the geomagnetic disturbances of July 11 and 17. A Special World Interval (SWI) was declared to accompany the great July 15 storm, while the other two, though predicted by the North Atlantic Radio Warning Service (NARWS), were accompanied by Alerts only.

These three geomagnetic disturbances in July, along with two severe disturbances in September for which SWI were declared (see list), were associated with 11 of the 16 whole-day radio disturbances of the quarter and with 33 of the 56 six-hour intervals of disturbed radio quality.

Of particular interest are the geomagnetic disturbances of July 23, August 20,

and September 18. These storms occurred approximately 27 days apart and are the first readily identifiable recurrent storms since before the recent sunspot maximum, with which the IGY period was chosen to coincide. Several other disturbances during the quarter exhibited characteristics normally associated with recurring storms—gradual beginning, moderate intensity, and long duration—but no obvious 27-day pattern was discernible.

Only five of the 11 geomagnetic storms recorded during the quarter were preceded by the type of observable solar activity normally followed by storminess.

The following is a list of major solar flares (those evaluated as 3 or 3+ in importance by at least one observatory), geomagnetic disturbances, world-wide geophysical Alerts, and SWI for the third quarter of 1959:

Jun	27*	11xx**	Magnetic storm begins
	28	1600	Alert issued
	29	00xx	Magnetic storm ends
		0728	Magnetic storm begins
		1600	Alert issued***
Jul	1	00xx	Magnetic storm ends
	8	0818	Class 3+ flare; slow S-SWF†
	10	0210	Class 3+ flare; slow S-SWF
		0514	Class 3+ flare; G-SWF†
	11	1623	Magnetic storm begins
	12	13xx	Magnetic storm ends
		1600	Alert issued
		2152	Class 3 flare; G-SWF
	14	0325	Class 3+ flare; S-SWF†
		1400	Class 3+ flare; slow S-SWF
	15	0802	Severe magnetic storm begins
		1600	Alert issued; auroras expected SWI starts††
	16	12xx	Severe magnetic storm ends
			SWI finishes
		1308	Class 3 flare; S-SWF
		2114	Class 3+ flare; S-SWF
	17	1638	Severe magnetic storm begins
	18	1600	Alert issued; auroras expected
	19	06xx	Severe magnetic storm ends
	23	04xx	Magnetic storm begins
	27	2050	Class 3 flare; slow S-SWF
	28	03xx	Magnetic storm ends
	29	2020	Class 3 flare; slow S-SWF
Aug	15	14xx	Severe magnetic storm begins
	16	1600	Alert issued

18	1020	Class 3 flare; S-SWF
19	09xx	Severe magnetic storm ends
20	0410	Magnetic storm begins
	1600	Alert issued
21	1130	Class 3 flare
26	03xx	Magnetic storm ends
Sept 1	1650	Class 3 flare; S-SWF
2	0110	Severe magnetic storm begins
	0721	Class 3 flare; slow S-SWF
	1600	Alert issued
3	2159	Resurgence of magnetic storm beginning September 2
4	1600	Alert issued; auroras expected
		SWI starts
5		SWI finishes
6	10xx	Severe magnetic storm ends
18	21xx	Severe magnetic storm begins
19	1600	Alert issued
20	1600	SWI starts
21		SWI finishes
22	21xx	Severe magnetic storm ends
25	0045	Magnetic storm begins
	1600	Alert issued
28	08xx	Magnetic storm ends

Notes:

* Owing to publication schedules it was not possible to include in the preceding report (*Bulletin No. 28*) the last few days of the previous quarter; these are therefore included in the present report

** "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined

*** No ending times for alerts are issued, as was done during the IGY; this is now left to the discretion of individual observatories

† Symbols for ionospheric effects are defined as follows:

S-SWF—sudden short-wave fadeout and gradual recovery

Slow S-SWF—slow short-wave fadeout (taking 5-15 minutes) and gradual recovery

G-SWF—gradual disturbance; irregular short-wave fadeout or recovery, or both

†† SWI's, when warranted, start at the time the associated Alert is issued; they finish at the end of the day indicated

IGY Bibliographic Notes

This is the seventeenth of a series of bibliographic notes on IGY and IGC-1959 programs and findings. The references are selected largely from a bibliography under preparation in the Science and Technology Division of the Library of Congress. (An interim IGY bibliography, covering the period January 1951-August 1958, prepared by the Library and published by the Academy with support of the National Science Foundation, is available from the Academy, 2101 Constitution Avenue, N. W., Washington 25, D. C., for \$1.00. The 84-page volume contains 704 references.)

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Status of World Data Center A Reports

The activities of IGY World Data Center A include the publication of five series of special reports presenting data and results obtained in IGY and IGC-59 activities. The reports issued to date, and those now in press or in preparation, are listed below.

Reports in the General series and in the Rocket and Satellite series may be obtained from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C. Individual reports in these series are priced at \$1.00 each; remittances must accompany orders of \$1.00 or less. Discounts are available for standing orders for all titles in these three series; for quantity orders in excess of 5 copies of a single title; and to public and institutional libraries. Further information on these discounts may be obtained from the Academy.

In addition to continued publication of IGY-IGC results as they become available, it is tentatively planned to include in the Rocket and Satellite series many of the US papers presented at the First International Space Science Symposium, held in Nice, France, January 11-15, 1960, under the auspices of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU).

General Report Series

1. Description of the Antarctic Circulation Observed from April to November 1957 at the IGY Antarctic Weather Central, Little American Station.

2. Preliminary Report on Expedition Down-

wind, University of California, Scripps Institution of Oceanography IGY Cruise to the Southeast Pacific.

3. Preliminary Reports on the IGY Pendulum, Gravimeter, and Seismological Programs at the University of Wisconsin.

4. Some Aspects of the Antarctic Atmospheric Circulation in 1958.

5. United States Program for the International Geophysical Year 1957-58.

6. United States Program for International Geophysical Cooperation—1959.

7. Interim Catalogue of Data in IGY World Data Center A.

Satellite Report Series

1. Processed Observational Data for USSR Satellites 1957 Alpha and 1957 Beta.

2. Status Reports on Optical Observations of Satellites 1958 Alpha and 1958 Beta.

3. Some Preliminary Reports of Experiments in Satellites 1958 Alpha and 1958 Gamma.

4. Observational Information on Artificial Earth Satellites.

5. Radio Observations of Soviet Satellites 1957 Alpha 2 and 1957 Beta 1.

6. Reports and Analyses of Satellite Observations.

7. Simplified Satellite Prediction from Modified Orbital Elements.

8. Ephemeris of Satellite 1957 Alpha 2 and Collected Reports on Satellite Observations.

9. Symposium on Scientific Effects of Artificially Introduced Radiations at High Altitudes.

10. The Determination of Ionospheric Electron Content and Distribution from Satellite Observations. (January 1960.)

Rocket Report Series

1. Experimental Results of the U. S. Rocket Program for the International Geophysical Year to 1 July 1958.

2. Flight Summaries for the U. S. Rocketry Program for the IGY, Part I: 5 July 1956-30 June 1958.

3. Flight Summaries for the U. S. Rocketry Program for the IGY, Part II: 23 May-31 December, 1958.

4. Magnetic Exploration of the Upper Atmosphere.

5. Upper-Air Densities and Temperatures from Eight IGY Rocket Flights by the Falling Sphere Method.

Glaciological Report Series

Reports in this series are available from IGY World Data Center A: Glaciology, American Geographical Society, Broadway at 158th Street, New York 32, New York. They are priced at \$3.35 each (\$3.00 + \$0.35 for handling); standing orders may be placed. Additional reports in this series are now in preparation.

1. Preliminary Reports of the Antarctic and Northern Hemisphere Glaciology Programs.

2. Oversnow Traverse Programs, Byrd and Ellsworth Stations, Antarctica, 1957-58: Seismology, Gravity and Magnetism.

Solar Activity Report Series

Reports in this series consist of highly specialized tabulations of data, and are prepared primarily for distribution to other IGY WDC's and to participating observatories. Inquiries about the solar-activity reports should be addressed to IGY World Data Center A: Solar Activity, High Altitude Observatory, University of Colorado, Boulder, Colorado.

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The National Academy of Sciences has prepared a teaching aid known as "Planet Earth" which is of value to students and teachers of the earth sciences. It consists of six large (34" X 48") posters in full color, a 44-page illustrated student brochure, and a Project Leader's Kit containing a variety of supplementary narrative materials. Prices are as follows:

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation-1960 as related primarily to United States programs.

Upper-Atmosphere Density and Temperature

The following report is based on material prepared by Robert Jastrow, Chief, Theoretical Division, Goddard Space Flight Center, National Aeronautics and Space Administration. More detailed treatments appeared in Astronautics, July 1959, and in the Journal of Geophysical Research, November 1959.

When the IGY began, upper-atmosphere densities and temperatures were relatively well known below a height of about 100 kilometers and less well known between 100 and 200 kilometers. Above 200 kilometers, atmospheric properties could only be extrapolated from lower-altitude data. These extrapolations were uncertain by factors of about 100 at an altitude of 500 kilometers and about 10,000 at 1000 kilometers.

The ceiling on density measurements was raised to 700 kilometers by the first data from the Vanguard I satellite (1958 Beta; see *Bulletin No. 11*), which yielded values at that altitude with an uncertainty factor of only 2. Other satellites before and after Vanguard I filled in the density curve at intermediate altitudes with about the same precision. Analysis of these measurements, combined with rocket data for lower altitudes, has revealed additional features that promise a broader understanding of upper-atmospheric dynamics. The most important among these, perhaps, is evidence that upper-atmosphere proper-

ties in the auroral zones are strongly affected by the outer Van Allen radiation belt (see *Bulletins 21* and *30*), and differ very greatly from those of temperate and equatorial latitudes.

Density

Analysis of Satellite Data: Atmospheric density is determined indirectly from satellite tracking data by analysis of changes in the satellite's period of revolution. Atmospheric drag causes a satellite to lose energy continuously during its lifetime. As its energy decreases, the satellite "falls" toward the center of the Earth, reducing its average altitude and, therefore, the time required for each circuit of the globe. Detailed calculations, based on the equations of satellite motion, are used to determine the quantitative relationships between the reduction in orbital period and the average air density in the satellite orbit.

The effect of air drag on a satellite orbit is shown schematically in Figure 1. Since

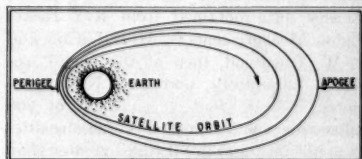


Fig. 1. Effect of Atmospheric Drag on Satellite Orbit. Drag at perigee reduces altitude of succeeding apogee.

density falls off very steeply with increasing altitude, the effect of drag near perigee, the lowest point in the orbit, greatly outweighs the effect at other points.

Density Fluctuations: Satellite density data show large fluctuations superimposed on the systematic variations described above. These fluctuations probably result from atmospheric heating produced by streams of energetic particles and radiation from the sun. The sun's surface boils and bubbles actively and continuously, occasionally emitting great gusts of plasma and radiation into the solar system.

L. G. Jacchia, of the Harvard College Observatory, has shown that the seemingly random fluctuations in upper-atmosphere density can actually be correlated with changes in the intensity of 10.7 centimeter radiation from the sun, which constitutes an excellent measure of general solar-surface activity at many wavelengths. In addition, the density fluctuations tend to be repeated every 27 days, which is the sun's period of axial rotation. Thus, it appears that heating and expansion of the upper atmosphere are also produced by radiations and corpuscular streams coming from definite spots on the sun's surface, which appear and disappear every 27 days in the course of solar rotation. In certain instances, the increase in satellite drag has been tentatively identified with the arrival in the earth's vicinity of corpuscular streams following major solar flares (see Fig. 2).

Latitude Dependence: A strong dependence on latitude is characteristic of the density data obtained from IGY rocket flights. Measurements by H. E. LaGow and J. W. Townsend, then at the Naval Research Laboratory, and their NRL associates, indicate that at a height of 200 kilometers the summer daytime densities in arctic latitudes are 6 times greater than corresponding densities at temperate latitudes. (LaGow notes, however, that this

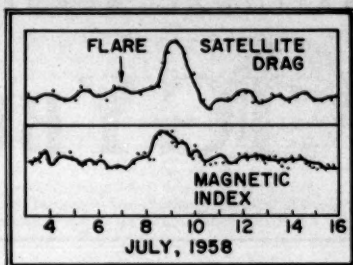


Fig. 2. Comparison of Satellite Drag Variation and Geomagnetic Disturbance Following Major Flare. (From L. G. Jacchia, 1959.)

apparent latitude effect may not be representative since the temperate region flight was made in 1951, at sunspot minimum, while the arctic flight was made in 1957, at the peak of sunspot activity.) LaGow also found that arctic densities vary with season and time of day: at an altitude of 200 kilometers, the northern atmosphere is twice as heavy during the day as at night and twice as heavy in summer as in winter.

LaGow presents a simple explanation for these daily, seasonal, and latitudinal variations. During the day, solar radiation probably heats the thin upper atmosphere and causes it to expand upward, producing a large relative density increase. This effect should be greater in summer than in winter, and greatest of all during the long arctic-summer day, when exposure to the sun is nearly continuous. These predictions agree with LaGow's observations.

Comparison of Rocket and Satellite Density Data: Satellite results do not show the strong latitude dependence which appears in the rocket data. Since satellite measurements always give the density at perigee, they automatically sample a broad range of latitudes because of the rotation of perigee in the plane of the orbit. In the orbit of Vanguard I, for example, the latitude of perigee moves from 33° N to 33° S

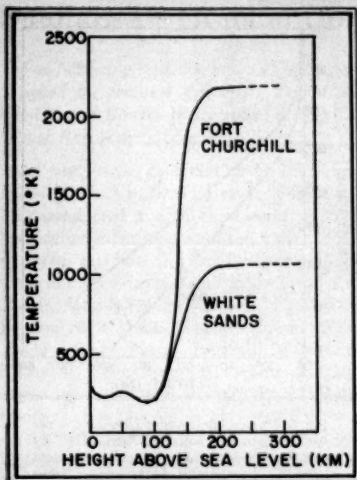


Fig. 3. Upper-Atmosphere Temperatures Determined from Rocket Data. Fort Churchill is at 59° N, in the Canadian auroral zone; White Sands is at 33° N. (From Horowitz and LaGow, 1958.)

every 41 days. Although Vanguard I has been in orbit for more than a year, the tracking data have thus far shown no significant changes correlating with latitude variations.

Temperature

Direct temperature measurements have not been made in the upper atmosphere, but temperatures can be determined mathematically from density data on the basis of the relationship between altitude and density.

Using this relationship, LaGow and his associates determined atmospheric temperatures between altitudes of 150 and 200 kilometers over White Sands, New Mexico, and over Fort Churchill, in the Canadian auroral zone. They found that during a summer day the upper-air temperature in

the auroral zone is approximately 2000°K (3000°F), while it is a relatively cool 1100°K (1500°F) over New Mexico (see Fig. 3).

Van Allen Radiation Belts: The particles in the Van Allen radiation belts (see *Bulletins 21 and 30*) may provide a further explanation for the differences in atmospheric properties between the temperate and arctic zones. In the Van Allen belts, particles trapped by the earth's magnetic field spiral along the lines of magnetic force. Those in the outer belt are funneled along the lines of force into the arctic and antarctic zones, where the belt dips downward and disturbs the atmosphere, a condition that does not exist at other latitudes.

Interaction between the trapped particles and the polar atmosphere has two major consequences: (i) It appears that the polar aurora results from excitation of the high atmosphere in the Arctic and Antarctic by collisions of air atoms and molecules with the particles trapped in the outer belt; (ii)

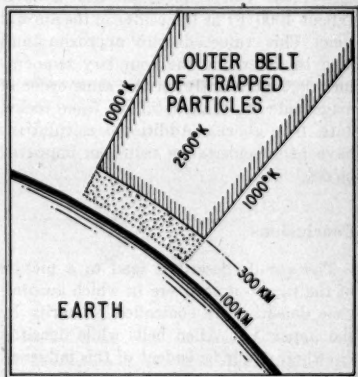


Fig. 4. Temperature Model Showing Heating of Upper Atmosphere in Auroral Zone by Contact with Particles of Outer Van Allen Radiation Belt. The "horns" of the outer belt approach closest to the earth in the auroral zones (see Bulletin No. 30).

the atmospheric temperature of the auroral zones is raised by the energy transferred in these collisions.

The theory of upper-atmosphere heating by magnetically trapped charged particles predates the discovery of the Van Allen belts. However, the Van Allen data, supplemented by Sputnik III results and by rocket measurements, provide an opportunity for quantitative tests of this theory. I. Harris and Robert Jastrow constructed an idealized model in which the heating effect of the outer Van Allen layer is confined to a definite region in the auroral zone, with boundaries kept at the "temperate" level of 1000°K (about 1350°F). The rate at which heat is transferred to the air within this zone is calculated from the combination of all rocket and satellite observations of the Van Allen particles. Figure 4 shows a schematic representation of this model. Heat conduction may be computed analytically using the indicated boundary conditions. Harris and Jastrow have shown in this way that the temperature must reach approximately 2500°K (about 4000°F) at the center of the auroral zone. This value, despite approximations used to determine the boundary temperature, is, significantly, of the same order of magnitude as that obtained from rocket data (see above). Additional calculations have been undertaken using an improved model.

Conclusions

The results described lead to a picture of the upper-atmosphere in which auroral-zone densities are controlled primarily by the upper Van Allen belt, while densities elsewhere are independent of this influence. If this picture is correct, two distinct atmospheric models must be considered.

The first, the Temperate-Equatorial atmosphere (curve T-E of Figure 5), is obtained from White Sands rocket data and

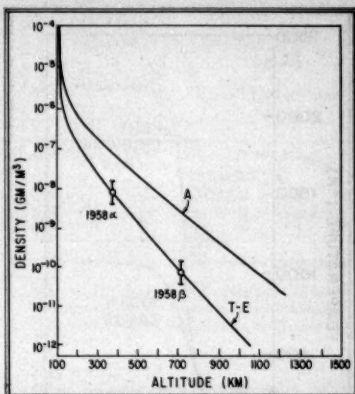


Fig. 5. Upper-Atmosphere Density Curves for Temperate-Equatorial Regions (T-E) and for Auroral Zone (A). Rocket data used for portions of both curves below 200 kilometers; above 200 kilometers, T-E curve based on atmospheric-drag data for 1958 Alpha (Explorer I) and 1958 Beta (Vanguard I), while A curve extrapolated from rocket data on the assumption of constant temperature.

computations based on the effects of drag on the orbits of 1958 Alpha (Explorer I) and 1958 Beta (Vanguard I). All density data used for this model were obtained at north and south latitudes no greater than 33°.

The second, the Auroral atmosphere (curve A in Figure 5), is based on rocket observations at Fort Churchill extrapolated above 200 kilometers on the assumption that temperature remains constant. The constant-temperature assumption is based on the LaGow rocket measurements, which indicate little temperature variation between heights of 170 and 210 kilometers.

It is interesting to note that on the basis of the T-E model the oxygen atmosphere will give way to a hydrogen atmosphere at an altitude of approximately 1200 kilometers.

Sunflare II—Rocket Observations of Solar Activity

The following report is based on material supplied by Herbert Friedman, Talbot A. Chubb, and Robert W. Kreplin, of the US Naval Research Laboratory.

As part of its contribution to IGY and IGC-59, the US Naval Research Laboratory conducted a number of solar rocket-astronomy experiments. In the most recent of these, Sunflare II, 12 Nike-Asp rockets were launched from Point Arguello on the Pacific Missile Range between July 14 and September 1, 1959. Sunflare I, the IGY Rocket Flare Patrol Program, was conducted at Point Mugu, California, in July and August 1957 (see *Bulletin No. 7*). Both Sunflare programs represented continuations of the NRL rocketoon program of solar observation conducted in the summer of 1956. The Sunflare II series was supported by a grant from the National Science Foundation.

The objective of the Sunflare II experiment was to obtain further direct information about the nature of solar flares—in particular, about the radiations emitted by flares as compared with those emitted by the quiet sun. (*Bulletins 7, 12, 19, 23, and 29* also discuss this subject.) Of the 12 Sunflare II launchings, eight were completely successful, reaching heights between 130 and 150 miles; in the best flights, data were telemetered continuously for nearly eight minutes. Three of the eight rockets were launched during flares and five were launched when the sun was quiet or only mildly active.

Flares and Related Phenomena

A solar flare is usually seen as a sudden brightening of the sun's surface near a sunspot. A flare reaches its peak brightness—as much as 10 times that of the surrounding photosphere when viewed in $H\alpha$, the red light of hydrogen—within minutes, during which a large flare may expand over

an area of the sun's surface ranging from 100 million to a billion square miles. The flare's decay is slower, ranging from a half hour to several hours, depending on its size. Visible flares are flat and extend parallel to the sun's surface, remaining essentially stationary throughout their lifetimes. They are three to four times as thick as the chromosphere (the lowest level of the solar atmosphere, extending to a height of about 15,000 miles above the surface), and their uppermost portions reach into the corona. Flares grow outward at speeds only rarely exceeding about 10 miles per second.

Flares are one of a group of phenomena constituting "solar activity," which directly affects the earth's upper atmosphere, frequently interfering with radio communica-

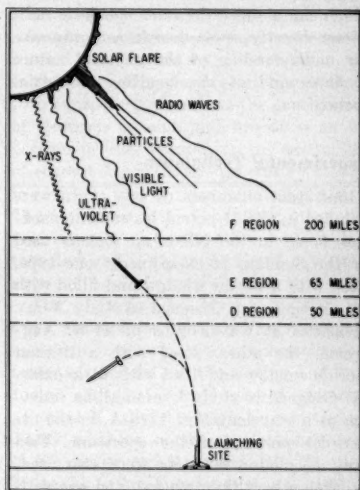


Fig. 6. The Sunflare Experiment. The two-stage experimental rocket is launched immediately after a flare is reported, penetrating the ionospheric layers and measuring the flare radiations. Comparative wavelengths of the radiation spectrum are suggested schematically.

tions. The terrestrial effects associated with flares fall into two categories: (i) those occurring almost immediately following the beginning of a flare, such as the radio fadeouts (also termed sudden ionospheric disturbances, or SID), and caused by solar X-rays; and (ii) those beginning about a day later, such as geomagnetic storms, as a result of the arrival at the earth of the high-speed stream of charged particles ejected by the flare.

Although the sun is observed daily in visible light for the purpose of forecasting SID and magnetic storms, many unknowns make accurate prediction extremely difficult. For example, what appears in visible light to be a relatively minor solar disturbance may be followed by great terrestrial disturbances, while an apparently large solar event may produce only minor effects at the earth. Rocket astronomy techniques, which can observe the sun's energetic radiations directly, seek therefore to improve our understanding of the physical nature of flares and of the resulting terrestrial phenomena.

Experimental Techniques

Ionization chambers of two types were included in the 55-pound instrument packages flown in the Nike-Asp rockets used for the Sunflare II experiment: one type, fitted with a Mylar window and filled with dry nitrogen, was designed to study X-ray intensities at wavelengths of 44-60 Angstroms; the other, fitted with a lithium fluoride window and filled with nitric oxide, was designed to study Lyman-alpha radiation at a wavelength of 1216 Å, in the ultraviolet portion of the spectrum. Two types of photon counters were also used, one with a beryllium window and one with an aluminum window. The former was designed to cover the 2-8 Å region and the latter the 8-18 Å region of the X-ray spectrum. Finally, two types of scintillation counters, or proportional counters, were used to study the intensity of "hard," or

penetrating, X-rays. One was sensitive to the 2-20 kev range (kev = thousands of electron volts) and the other to the 20-200 kev range. The data obtained by each of these radiation detectors were telemetered to tape and oscillographic recorders mounted in instrumentation vans specially equipped for the rocket astronomy experiments.

Since it was necessary to the success of the experiment that a rocket be launched as soon as possible after the start of a flare, both optical and radio methods were used for flare detection. An NRL team at the Lockheed Solar Observatory in Los Angeles observed the sun's disk in the light of the red line of the hydrogen spectrum, transmitting their observations and flare warnings to the launching site by private telephone. Meanwhile, radio observations of flare effects on the ionosphere were conducted from the NRL van at Point Arguello. These observations of sudden short-wave fadeouts and sudden cosmic-noise absorption, at a frequency of 18 megacycles per second, were reliable indicators of flares of sufficient intensity to cause ionospheric disturbances.

Except in background measurements, an attempt was made to time the rocket launchings—planned on a one-minute count-down basis—so that measurements could be made during the expected peak intensity of the flare. Of the three rockets launched during flares, one reached its peak altitude at the time of maximum intensity of a class 2+ flare. (Flares are classified on the basis of the solar-disk area covered, using a scale ranging from 1 [smallest area] to 3 [largest] with + and - signs indicating positive or negative variations from the average of any class.)

Results and Conclusions

Measurements made during NRL's pre-IGY rockoon program indicated the existence of a background of X-rays in the upper atmosphere with energies perhaps as

high as 50 kev. However, the flux was too small to permit directional measurements that could identify the radiation with the sun. The Sunflare I measurements, during the IGY period, detected intense flashes of 6-7 kev X-rays accompanying solar flares. These flashes were of sufficiently short wavelength (or sufficiently great hardness) to penetrate to the base of the D region of the ionosphere and produce the D-region ionization required to explain radio fade-outs. It was theorized that this production of X-rays in the solar atmosphere could result from heating of the corona above the flare to temperatures greater than 10,000,000° C. The temperature of the quiescent corona is about 500,000° C.

The Sunflare II experiment provided further important information with the discovery of the emission of extremely energetic X-rays during the most active phases of large flares. In the early phases of the three such flares observed, X-rays with energies as high as 90 kev were detected. Moreover, these X-rays were *not* emitted as brief bursts but persisted throughout the full six minutes the rockets were above the absorbing portion of the atmosphere (or about 45 kilometers, the height to which the hardest X-rays penetrated). From start to finish of a flight, it is possible to detect a softening of the spectrum.

During the class 2+ flare mentioned above, the total X-ray flux in the energy range 30-90 kev (0.41-0.14 A) was about 10^{-6} erg/cm²/sec, decreasing by approximately a factor of 2 for each 5-6 kev increase in energy within this range. This spectral distribution appears to be best explained by the existence of a collection of thermal sources in the solar atmosphere, and the production of 80-90 kev X-rays implies local temperatures—in the vicinity of the flare—of the order of 100,000,000° C.

When the few available measurements of solar X-rays from class 2 and 3 flares are averaged, the following correlations of flux with wavelength are obtained: for wave-

lengths of 20-100 A, the flux is 2 ergs/cm²/sec; for 8-20 A, the flux is 3×10^{-2} erg/cm²/sec; and for 2-8 A, it is 10^{-2} erg/cm²/sec. The total X-ray flux affecting the E region during the class 2+ flare was roughly twice the quiet-sun value.

The Sunflare II results indicate that high-energy X-rays are a normal solar emission. It appears that even the quiet sun emits a broad spectrum of X-rays extending to very high energies, although the flux is very low, and that the entire spectral range of X-ray emission is enhanced by the intense excitation accompanying a flare.

Possible Origins of High-Energy Solar X-Rays

Several possible mechanisms have been proposed to explain the generation in the solar atmosphere of such high-energy X-rays. X-ray emission is produced by the interaction of high-speed electrons with the coronal gas or with magnetic fields at the sun's surface. The close association of flares with sunspots implies that the acceleration of electrons to such high speeds is an induction process (similar to the production of current in an electric generator) related to rapid changes in magnetic-field strength. The higher the rate of change of magnetic-field strength, the greater the induced electron flow and the stronger the X-ray emission.

The suggestion has been made that the sun's atmosphere contains Van Allen-type radiation belts which trap energetic electrons accelerated in the vicinity of sunspots, and that these trapped electrons generate X-rays. According to one theory, X-ray emission of the strength measured in the earlier rocket experiments (Sunflare I) could be produced by a few hundred relativistic electrons per cm³ in a coronal region having a magnetic-field strength of only 10 gauss. (Relativistic electrons are electrons moving at sufficiently great speeds—about one-half the speed of light, or faster—so that physical effects predicted

by the theory of relativity become noticeable; the earth's magnetic field at the equator has a strength of about .34 gauss.)

Soviet astronomers observing the strength of solar magnetic fields in flare regions, with a resolution of a few hundred miles, report that flares begin at "null points" in regions of very high magnetic-field gradients. They further report that the flare

process wipes out these gradients, thus dissipating the stored magnetic energy. Theoretically, such a mechanism may produce X-rays with energies as high as several million electron volts. The process is similar to the "magnetic pinch" effect scientists are seeking to produce in laboratory experiments to achieve controlled nuclear fusion.

Oceanographic Observations at IGY Wilkes Station, Antarctica

The following material is based on a report by Willis L. Tressler of the US Navy Hydrographic Office, who was Station Scientific Leader at IGY Wilkes Station, 1957-58.

During the 1957-58 IGY scientific program in Antarctica, studies were conducted at US-IGY Wilkes Station on floating ice, currents, tides, and bottom sediments; some hydrographic and bottom-topography survey work was also accomplished. Wilkes Station is situated at 66°15'25"S, 110°31'39"E, in the Windmill Islands on the Budd Coast of East Antarctica (see Fig. 7). The station is at the western end of Clark Island.

The condition and extent of fast ice and floes were observed daily from the aurora tower and, on all except days of extremely poor visibility, movements of ice were photographed with a 16-mm, time-lapse motion picture camera from the same location. A portable tide gage was installed and continuously operated for slightly longer than one complete lunar cycle in the autumn and was again placed in operation in the spring for approximately two months. A series of ten bottom samples was obtained, extending from the shore to deep water in

Newcomb Bay. Survey work was accomplished in which the position and orientation of Clark Island and the northern islands were tied in with a point on Holl Island accurately determined by astronomical techniques.

Description of Region

Clark Island is characterized by exposed, rocky areas between large, permanent snow fields, as are the adjoining islands of the Windmill group. (Recent gravimetric and radio soundings show Clark "Island" actually to be a peninsula extending outward from the ice-covered Budd Coast.) In winter, much of the rocky area is snow covered, but during the summer months much rocky terrain is exposed. The snow fields merge inland into a single extensive snow slope which ends in a sinuous shear moraine at an altitude of about 500 feet. (Moraines are features composed of rock material deposited by glaciers; shear moraines are found on the glacier surface and consist of materials that have moved upward along shear planes.) Beyond the shear moraine, the great continental ice sheet extends to the pole, some 1400 miles south.

According to John Hollin, Chief Glaciologist at Wilkes Station in 1957-58, the glacial ice retreated from most of Clark Island approximately 12,000 years ago. Relieved of its load, the land rose about 100 feet and apparently is continuing to rise at the present time, as shown by raised beaches in the vicinity of the station.

Several coves indent the south and southwest shores of Clark Island. Wilkes Station is situated between two of these coves, provisionally named "Ramp" and "Tide Gage" coves (Fig. 7), an especially suitable location for oceanographic observations. The water in the two coves averages about 40 feet in depth and rock pinnacles were observed in several places. From a reconnaissance sounding made in 1957, Newcomb Bay does not appear to exceed a depth of about 270 feet.

In the vicinity of the station, some shoal areas and at least two submerged pinnacles, which are not uncovered at low tide, have

been charted. Both of these obstructions are outside the main anchoring area, which was wire-dragged to a depth of 40 feet by the *USNS Greenville Victory* in 1957. The greater part of Newcomb Bay offers a safe anchorage for large vessels and the bottom provides good holding ground. A prominent, permanently ice-covered rock (Fitzpatrick Rock) stands in the middle of the entrance to the bay; there is deep water all around this rock at a distance of not more than about 50 feet.

Weather Conditions

Situated along the coast of East Antarctica, where it could receive the moderating effect of the ocean, Wilkes Station did not suffer the extreme Antarctic weather that other US stations experienced. When open water surrounded the station, temperatures usually remained near about 30°F. The average monthly wind velocity was

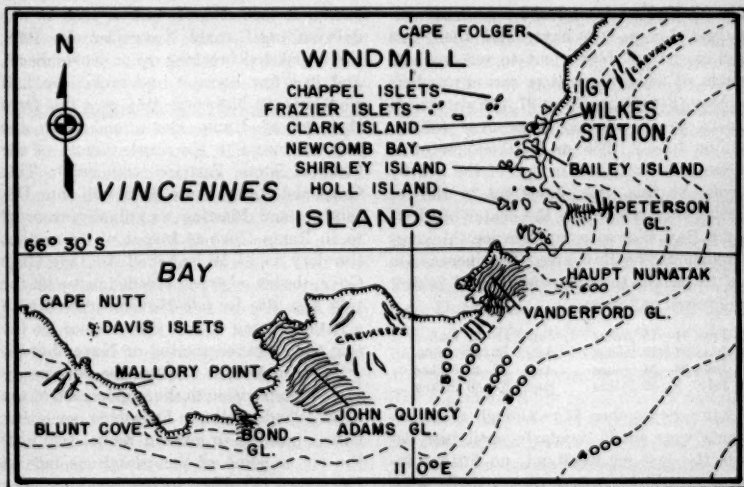


Fig. 7. Windmill Islands-Vincennes Bay Area of East Antarctica. Approximate position of IGY Wilkes Station is shown. "Tide Gage Cove" is just north of the station, "Ramp Cove" just to the south; "Base Point" is at the end of the peninsula, just west of the station.

often below that of other US stations and there were many long periods during which there was a complete absence of wind. The frequency of winds exceeding 50 knots and the high peak gusts at other times, however, have earned for Wilkes the reputation of being a windy station.

Sea-Ice Studies

Observations of ice conditions in the portion of Vincennes Bay surrounding Wilkes Station were made daily from the aurora tower or from nearby hills. Open water persisted around the Station, and in Newcomb Bay between Clark and Bailey Islands, until late autumn.

Formation of Fast Ice: As autumn progressed, rocks along the shores of the coves gradually became ice-covered from spray and breaking waves, but fast ice (i.e., attached to shore, etc.) did not form in the coves and for several miles seaward until late May. New ice formed repeatedly, remained for a few days, and then was broken up and blown out to sea by high winds, of which there were record numbers in May. Finally, on May 27, the waters adjacent to the station froze over solidly, and on June 9, 1958, an ice thickness of 14 inches was measured in one of the nearby coves. At this time, holes cut in the ice farther offshore and in the center of Newcomb Bay showed a uniform ice thickness throughout the Bay area. The increase in ice thickness through the austral winter progressed as follows:

June 11—15 inches	July 11—31 inches
June 21—21 inches	Aug. 8—42 inches
June 25—24 inches	Aug. 25—42 inches
July 8—30 inches	Sept. 16—50 inches

After September 16, although measurements were made regularly until just before the fast ice went out, no further increase in thickness was observed. In holes chopped through the ice to measure thickness, ice formed again rather rapidly during the colder months. In a hole chopped

on June 20, an ice thickness of 14 inches was measured five days later. During the winter, snow blew in around the shore lines, forming a smooth slope between the bay ice and the rocky hills and snow fields adjoining the coves.

Extent of Fast Ice: Once the fast ice had formed in Vincennes Bay, it slowly grew seaward to what appeared to be a line about two or three miles east of the Frazier Islets, some 10 miles from shore (see Fig. 7). Fast ice never reached the islets during the winter of 1957-58. The fast ice extended considerably beyond the Chappel Islets, however, about five miles west of the station, and continued northward parallel with the shore as far as observers at the station could see. This fast ice to the north remained until late summer, and was still in place when the 1957-58 Wilkes Station party departed, on February 6, 1959.

In 1957, break-up of the ice in southern Vincennes Bay and in Newcomb Bay occurred in late August, but in 1958 it was delayed until early November. In 1958, the ice started breaking up on November 6, and in a few hours it had broken up half way out into Newcomb Bay on a line from the end of Ramp Cove, and from the bay northwest to the northernmost of the Chappel Islets. Fast ice remained in Tide Gage and Ramp coves until well into December, and blasting was finally resorted to in Ramp Cove to free it of ice so that the dory could be launched. In Tide Gage Cove, the ice edge had receded just past the tide gage site by late November, and with a little blasting to free the rocks of ice the tide gage was reactivated on November 28.

South of Wilkes Station, the fast ice remained in position in the region east of the outer islands well into December, such that it was possible to make a weasel trip over the ice to some of the islands as late as December 17. After spring breakup, open water surrounded the station and extended as far as one could see toward the Frazier Islets.

Pack Ice: On some days, a line of pack ice (large accumulation of closely packed floating ice) with numerous bergs could be seen near the northern horizon, having apparently been blown in from farther north or west. Small block and brash and occasional small floes of fairly thin ice were carried past the station by wind and currents from time to time. (A "block" is a fragment of sea ice 6-30 feet in diameter; "brash" is less than 6 feet in diameter; a "floe" may be any sea-ice fragment, but here refers to those greater than about 30 feet across.)

During February 1957, large masses of pack ice moved into Newcomb Bay from the north, seriously interfering with small boat movements. The head of Newcomb Bay remained closed by fast ice, which served as a source for brash and block carried out of the bay by wind and currents. In 1958, the strait between Shirley and Bailey islands remained frozen much longer than it had in previous years.

Conductivity and Salinity of Fast Ice: Electrical conductivity of the fast ice was measured at about the time of each ice-thickness measurement. Melted water from clean ice samples taken 4-6 inches beneath the ice surface were used. The conductivity, hence the salinity, of the samples varied throughout the observation period, showing no particular trend whatsoever. The conductivity level in December was about the same as when first measured on June 11. Throughout the period, salinity varied between 5‰ (parts per thousand) and 8‰. In samples taken from ice hummocks formed above submerged rocks in Ramp Cove, however, salinity decreased steadily until December 4, 1958, six months after formation of the ice, when it was less than 1‰. It is apparent from these studies that brine seeps upward in the ice.

Movement of Cape Folger: Studies of the movement of Cape Folger, an ice point nine miles north of the station, were begun

on March 25, 1958, and continued until December 23, 1958. A signal pipe was set in bedrock on the ridge across from the tide gage, and a bench-marked observation point was established on a rock ridge just south of the station's recreation hall. From time to time, a theodolite set up over the bench mark was used to measure the angle between the signal pipe and the face of Cape Folger. On the basis of these observations, it was calculated that Cape Folger moved 130 feet west during the nine-month period at an average daily rate of approximately one-half foot. The rate was not at all constant, but varied from 0.17 to 1.42 feet per day. This rate is slow compared with that of the Vanderford Glacier, which was found by the Wilkes glaciological team (John Hollin, Caspar Cronk, and Richard A. Robertson) to be nine feet per day.

Tide Records

A portable tide gage furnished by the Navy Hydrographic Office was installed on the rocky shores of Tide Gage Cove. Although the tide gage was installed in mid-February 1958, ice conditions made it impossible to obtain continuous and relatively uninterrupted records until early March.

Tidal Measurements: A more or less continuous record was obtained from March 5 through April 19, 1958, in the austral autumn, and from December 15, 1958, through February 2, 1959, in the spring and summer. During the autumn period, the maximum high-tide, based on an arbitrary datum, was 8.2 feet; the lowest tide was 1.7 feet, giving an extreme range of 6.5 feet. The maximum daily range was 5.8 feet, the minimum 0.7 feet. The average daily range for the autumn period was 3.3 feet. It was observed on several occasions during autumn that at neap tides (about midway between the times of full and new moon) there was considerable slack water and consequent lessening of tidal currents.

In the spring and summer period, the maximum high-tide was 7.9 feet, the minimum low tide 1.6 feet, giving an extreme range of 6.3 feet, compared with 6.5 feet for the autumn period. The maximum daily tidal range in the spring-summer period was 6.0 feet, the minimum was 1.6 feet, and the average was 3.5 feet.

Mean Sea Level: Although the tidal observations did not cover a sufficiently long time interval to establish a true mean sea level, the averages were taken as a base for topographic surveys and other work at Wilkes Station requiring at least a tentative approximation of mean sea level. If the average height above the arbitrary zero datum (4.59 feet) for the autumn observation period is compared with the average for the spring-summer period (4.13 feet), a drop of 0.46 foot in mean sea level is found to occur in the latter period.

The occurrence of this phenomenon in other oceanic areas of the world has been pointed out by other workers during the past few years. Walter Munk gives a figure of 0.66 feet (20 cm) for this seasonal difference at Baltimore. (It should be remembered that the seasons are reversed in the two hemispheres; hence, the higher sea-level value occurs in September in the Northern Hemisphere and in March in the Southern Hemisphere.) Munk ascribed this seasonal difference in sea level to actual transport of water to and from the polar regions, rather than to the effect of heating and cooling of the water by solar radiation, evaporation, or other processes, as seems to be the case in low latitudes.

After the fast ice closed the coves and extended for several miles out to sea, a tidal crack developed along the shore. At high tides, water was extruded through this crack out onto the ice, while there seemed to be little vertical movement of the ice. (Other wintering-over expeditions have made limited tidal observations by following the vertical movement of the ice. These results can be only approximate, however,

and must be correlated with the rise and fall of open water to obtain more accurate values.)

Currents

Beginning in February 1958, time-lapse, 16-mm moving pictures of ice movements were taken from the aurora tower at Wilkes Station. These studies were made on virtually all clear days when there was open water with ice to photograph. Exposures were made at 30-second intervals at first, and later at intervals of 20 seconds. The film will be examined carefully to determine patterns and trends of the currents near Wilkes Station. At present, however, a few general statements can be made.

Current Patterns: It is readily apparent that strong tidal currents flow in and out of the coves and Newcomb Bay. In Tide Gage Cove, the current is strongest near shore on the side of the cove toward the station. Currents in Newcomb Bay appear strongest near shore, but a considerable current also flows in mid-bay. Currents flowing out of Tide Gage Cove meet currents flowing out around "Base Point," resulting in a large eddy at certain tide stages. On one occasion, two blocks of ice travelling in opposite directions were seen to collide with each other. A few hundred yards off shore, a countercurrent runs in a direction opposite to that of the inshore current. Far out on the horizon, large blocks of ice and small bergs could be seen moving southeastward toward the Midgley Island group.

Origin of Currents: Sometimes, ice movement near shore followed the direction of low cloud formations; most of the time, however, there was no correlation between direction of ice movement and wind direction as indicated by the movement of low clouds. Hence, the currents are most likely of tidal origin. A wind-direction indicator placed in the foreground when future ice-

movement pictures are taken, however, might yield further information on possible relationships between winds and currents in the vicinity of Wilkes Station.

In Ramp Cove, an oscillatory motion of ice blocks was seen at certain tide stages. When the *Magga Dan* (a Danish ship chartered by the Australians) anchored off the south side of Base Point, time-lapse moving pictures were made of her motions while riding at anchor in the hope that they would give some indication of current direction and changes. However, the ship seemed to swing about with little or no regularity, its motions bearing no resemblance to those that might be expected from orderly tidal changes.

Bottom Sediments

In February 1957, while the station was being established, several short cores and bottom-sediment samples were obtained in the deeper waters of Newcomb Bay. Because of considerable variation in the nature of these samples, another series was taken along a line from the shore outward to the deeper waters of Newcomb Bay for comparison and correlation. As soon as the ice had formed in Ramp Cove in June, this second series, of ten samples, was begun at a point about 30 feet from the shore at the head of the cove where the water was 6 feet deep. The series ended at a point where Newcomb Bay is about 225 feet deep.

Description of Sediments: Within the cove, bottom sediments are coarse and relatively well sorted, while in Newcomb Bay the sediment becomes much finer and sorting is poor. (Sorting here refers to degree of uniformity of particle size in the sample, e.g., a well-sorted sample is one of relatively uniform particle size.) None of the pebbles examined appeared to be freshly deposited, but gave indication of long residence in the area. Most pebbles were composed of gneissic, or banded, quartzite, with biotite the most abundant accessory mineral. Some

garnet was present, but it was not nearly as abundant as its widespread occurrence in the exposed rocks of the area would appear to indicate. Sand grains were almost all of medium sphericity with angular or sub-angular configurations. Most quartz grains exhibited a glassy surface texture. Frosted grains in some samples suggest the existence of old beach lines. Quartz was the dominant mineral in the bottom sediments, with feldspar, biotite, hornblende, and garnet occurring in smaller amounts.

Organic Material: Organic remains in the samples varied considerably from station to station, depending on the nature of the bottom sediment. The bottom of Ramp Cove was found to be fairly well covered with both brown and bright red algae having long kelp-like fronds and attached to rocks on the substratum. At the first station, the all-gravel bottom was bare of organic material, while at distances between about 160 and 220 yards out into the cove, some annelid worms and clam-shell fragments were recovered. These appeared to be the only organic remains in the cove proper, and it was not until the deeper water of the bay was reached that other organisms, such as sea cucumbers, brittle stars, and sea urchins, were recovered.

No sponge spicules such as abound in the sediments of the McMurdo Sound region were noted in the bottom sediments of either Ramp Cove or Newcomb Bay. Diatoms were observed only at the last station, well out in the bay.

At the time of spring breakup of the ice, the water around Wilkes was unexpectedly clear, making it possible to photograph the bottom through a few tens of feet of water. It was expected, from experience gained at McMurdo Sound, that by December the planktonic growth would be dense enough to greatly reduce the water transparency, but this never happened and the water remained very clear until the 1957-58 scientific party left Wilkes in early February. (At McMurdo the water was found to be

very clear in early November 1956, but by late December the transparency was greatly reduced and a 1/2-meter net haul produced a quart jar full of a thick mass of plankton.)

Apparently, the volcanic nature of the exposed rocks at McMurdo Sound offers more easily soluble nutrients, especially silica, in the spring turnover period, resulting in a dense crop of diatoms and probably contributing to the abundance of silicious sponges, which feed on the diatoms. Both of these organisms are very much less abundant at Wilkes, where granitic types of rock provide little in the way of nutrient

materials despite considerable runoff of surface water during the summer months.

This same condition was noted by the Soviet investigator, A. P. Lisitzin, in bottom sediments of the Indian Ocean and Pacific Ocean portions of Antarctic waters. Lisitzin reported a scarcity of diatoms near the Antarctic continent, where bottom sediments are composed predominantly of glacial material, while farther north the glacial material decreased and diatoms became predominant in the sediments. Lisitzin also noted that in parts of the Indian and Pacific Oceanic regions submarine volcanoes are associated with zones of diatom oozes.

IGY Bibliographic Notes

This is the eighteenth of a series of bibliographic notes on IGY and IGC-1959 programs and findings. The references are selected largely from a bibliography under preparation in the Science and Technology Division of the Library of Congress. (An interim IGY bibliography, covering the period January 1951-August 1958, prepared by the Library and published by the Academy with support of the National Science Foundation, is available from the Academy, 2101 Constitution Avenue, N.W., Washington 25, D. C., for \$1.00. The 84-page volume contains 704 references.)

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation-1959 as related primarily to United States programs.

Seismic Crustal Studies During the IGY

Part I: Marine Program

The following report is based on material compiled by G. P. Woollard, of the Department of Geology, University of Wisconsin. This report presents results of IGY seismological investigations in marine regions; Bulletin No. 34 will present results obtained in the continental program.

The IGY Seismology Program contained several categories: (i) earthquake studies, with emphasis on special investigations of long-period seismic waves in the earth's crust; (ii) seismic explorations of the structure of the earth's crust; (iii) study of microseisms; and (iv) Antarctic seismic investigations. (*Bulletin No. 1* describes the aims and organization of the Seismology Program in greater detail, and other *Bulletins* contain reports on results of various specific studies; where appropriate in the following material, special reference is made to some of these reports.)

The crustal studies program, with which the present report is primarily concerned, can be divided into two parts—marine studies and continental studies. Part I of this report is concerned with the marine program. The continental program will be discussed in *Bulletin No. 34*.

Three US scientific institutions collaborated in carrying out the marine program: the Scripps Institution of Oceanography of

the University of California, the Lamont Geological Observatory of Columbia University, and the Woods Hole Oceanographic Institution. The marine seismic program was also materially aided by the direct participation of scientists from other nations and by naval ships of Brazil, Argentina, and the Union of South Africa.

Techniques and Interpretation

Much valuable information about the structure, density, and composition of the earth has been gained during the past 50 or 60 years through study of seismic waves generated by earthquakes. Because of the great amounts of energy released in these catastrophic natural phenomena, earthquake seismology has been particularly useful in providing knowledge of the deep interior of the earth. However, the usefulness of earthquakes for more detailed studies of the earth's crust—the relatively thin outer shell—is limited by the difficulty of establishing the precise location and time of an earthquake shock. For this reason, the primary tool used by seismologists for crustal studies is explosion seismology.

The technique of using artificial explosions to generate seismic waves provides relatively reliable information about the earth's crust and about the mantle—the layer directly beneath the crust. In this

technique, the exact location and time of the explosion can be readily determined. The seismic waves reflected or refracted by the interfaces between rock types of different density are detected by an array of seismometers at a known distance from the "shot point." The resulting records can then be used to compute travel times and wave velocities in the various crustal layers penetrated by the waves. These, in turn, are used to estimate the density, composition, and thickness of the layers.

In the deep ocean, where it is not feasible to lay out a series of seismometers at known distances from the shot point, two ships are used. One acts as a stationary shot point and the other as a movable recording station, with one or more hydrophones suspended at some depth determined by the thermal structure of the water and the local "noise" conditions. Distances are usually computed from the travel times of the sound pulses through the water between the ships. This technique requires numerous shots at varying distances up to about 100 kilometers in order to obtain an adequate amount of data.

Two basic types of elastic waves are generated in the earth by earthquakes and explosions: compressional, or "P", waves, and shear, or "S", waves. P waves, also termed longitudinal waves because particle motion is parallel to the wave's direction of travel, can be produced by explosions or by dropping large weights. S waves, also referred to as transverse waves because particle motion is at right angles to the direction of travel, are produced primarily by the shearing or tearing motion of earthquakes. Since S waves are difficult to produce artificially and are not transmitted through liquid material, the artificial seismic technique depends upon the use of P waves.

Seismic studies of the earth's crust in various parts of the world have shown the average crustal thickness to be about 35 kilometers beneath the continents and about 5 kilometers beneath the oceans. In gen-

eral, the continental crust is thicker beneath major mountain systems and thinner in coastal regions and other low-lying areas. The oceanic crust is thickest under island arcs and mid-oceanic ridges and thinnest under the deep trenches associated with the island arcs.

The crust is separated into two layers by most seismologists: an upper, essentially granitic layer, in which seismic-wave velocities are generally in the vicinity of 6.0 kilometers per second, and a denser, essentially basaltic lower layer, with seismic-wave velocities of about 6.5-7.3 km/sec. The thickness of these two layers varies greatly from place to place, and the granite layer appears to be absent beneath most oceanic areas.

Overlying the crust in most continental regions are layers of unconsolidated and semiconsolidated sedimentary materials, a few kilometers thick at most, in which wave velocities are lower than in the crust. In the oceans, the sedimentary materials range from about 0.5 to 1.0 kilometers in thickness. In the upper part of the mantle, just beneath the crust, seismic wave velocities are about 8.0 km/sec, and increase with depth. (A general increase with depth and density is also characteristic of wave velocities in the crust.) The interface between the base of the crust and top of the mantle is known as the Mohorovičić discontinuity, after its discoverer. The mantle is thought to consist essentially of peridotite.

Marine Program Results

About one-fourth of the seismic measurements in the marine program included the entire crustal thickness above the Mohorovičić discontinuity. Other measurements were confined to the bottom sediments overlying the crust and to the crustal material immediately beneath them. Most of the seismic studies used refraction measurements, but reflections were made where only the bottom sediments were being investigated. (*Refraction* requires a sharp

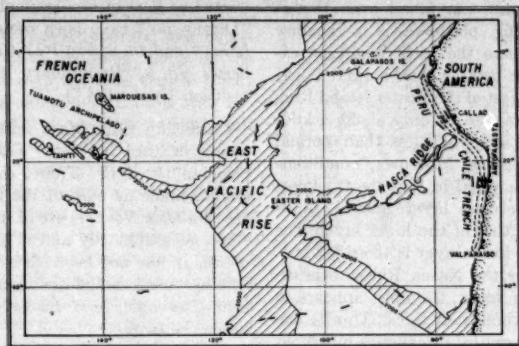


Fig. 1. Seismic Observations (short lines) in the South Pacific and on the West Coast of South America. Shading represents regions where bottom depth is less than 2000 meters.

discontinuity in the velocity of the medium at depth. A wave striking the discontinuity at the "critical angle" is refracted along the top surface of the lower, denser, higher-velocity material and is then refracted back continuously into the upper medium as a series of rays, also at the critical angle. The best reflections are at angles less than the critical angle; hence, the receivers must be relatively close to the source. In general, reflections are most useful for shallower studies and refractions for deeper studies of the crust and upper mantle.)

The total marine area covered by the participating groups was almost global in extent. The Scripps Institution of Oceanography concentrated its activities in the South Pacific between French Oceania and the coast of South America. Areas of particular interest were the Tuamotu Archipelago, the East Pacific Rise, and the Peru-Chile Trench. (See Figure 1.)

The Lamont Geological Observatory, partly in collaboration with the Woods Hole Oceanographic Institution and partly with research vessels made available through the IGY Committees of Brazil, Argentina, and the Union of South Africa, studied the Caribbean Sea between Central America and the Greater Antilles of the West In-

dies; the eastern continental border of South America from Buenos Aires, Argentina, to Cape Horn; the Scotia Sea area between the Falkland Islands and the Sandwich Islands; the Cape of Good Hope area; and the Gulf of Aden, Red Sea, and Mediterranean Sea.

South Pacific: In general, these oceanic measurements corroborated earlier seismic studies in the North and Central Pacific. In most places, the bottom sedimentary layer is only a few hundred meters thick, except in the equatorial carbonate area where the thickness is about two times the normal oceanic value of a few hundred meters. There is, perhaps, more variation in overall crustal thickness in the South Pacific than observed previously in other Pacific regions. Although the thickness of the main crustal layer, having a velocity of about 6.7 km/sec, is fairly constant, many stations showed an intermediate layer averaging about 1 kilometer in thickness and lying between the crust and the overlying sediments. Wave velocity in this intermediate layer varied between 4 and 6 km/sec.

Unusual findings were made in four areas: (1) In a deepwater embayment in the Tuamotu Island platform, normal

oceanic structure was found even though the surrounding platform is a shallow water area where the crust might be expected to have greater than normal thickness. (2) Just east of the Easter Island Rise, the crust appears to be only about 4 kilometers thick, somewhat less than normal for oceanic regions. Moreover, conditions here are also unusual in that the thickness of the upper crustal layer, about 2 kilometers, equals that of the lower layer. The velocity of the lower layer is about 6.7 km/sec. (3) Under the Nasca Ridge, beneath 2900 meters of water, the crust appears to be about 15 kilometers thick. This is one of the greatest crustal thicknesses measured in an oceanic region. (4) At four locations on the Easter Island Rise, no velocity greater than 7.5 km/sec was observed despite unusually long profiles. This is also an area where the heat flow in the bottom materials was observed to be about five times the normal value. As crustal conditions and heat flow appear normal in other parts of the Easter Island Rise, this correlation strongly suggests that the mantle velocity may be affected by abnormal thermal conditions, possibly related to convection currents in the mantle.

The measurements in the Peru-Chile Trench area are of particular interest. Off Antofagasta, Chile, a line of measurements parallel to the axis of the trench and about half way between the axis and the top of the continental slope (Fig. 1) shows that the base of the crust is about 23 kilometers below sea level, or about 20 kilometers below the sea bottom. Along the trench axis, the base of the crust is about 10.5 kilometers below the ocean floor; west of the axis the mantle is at a normal oceanic depth of about 6 kilometers below the ocean floor. This suggests a normal pattern of thickening as the continent is approached, with no observable superimposed effect related to the trench. A similar series of oceanic and trench-axis measurements off Callao, Peru, corroborate those to the south.

(Additional results of these studies, con-

ducted as part of oceanographic expedition "Downwind," have been presented in *Bulletins 7 and 16*, and in *IGY General Report Series No. 2*, "Preliminary Report on Expedition Downwind.")

Caribbean Sea: Most seismic measurements in the Caribbean Sea were made prior to the IGY. These, combined with studies made as part of the IGY program (see *Bulletin No. 21*), are of special interest since, geographically and in terms of water depth, it has not been clear to geologists whether such island-arc areas are continental, oceanic, or a transition phase between the two.

The results obtained are best summarized in Figure 2 of *Bulletin No. 21*, which shows a profile section across the Caribbean from Cuba to Venezuela. The outstanding points brought out by this profile are (1) The crustal thickness does not always conform to water depth. (Normally, the deeper the water, the thinner the crust, and vice versa.) (2) Internally, the crust is complex both structurally and in terms of the number of layers present. (3) Both continental-type structure and structure normally associated with oceanic conditions are present. (4) As was observed in the Peru-Chile Trench, the Bartlett Trough does not appear to involve the crust as a whole, but only the upper crustal layers and the overlying unconsolidated and semi-consolidated sediments.

The geological significance of the intermediate velocity values observed here, in the range 4-5.5 km/sec, is not clear. Because of the geographic location and because similar velocities have previously been observed in surface limestones, these values might indicate the existence of carbonate sedimentary rocks lying above the crust. Similar velocities are found in volcanic rocks, however, and velocities over 5 km/sec might also be attributed to crystalline granite at shallow depths.

Continental Border off Eastern South America: More than 70 seismic measure-

ments were made along the Argentine coast during the IGY, mostly within the continental shelf area. Although none of the measurements gave the total crustal thickness, much geologic information was obtained. In general, the continental-shelf section is characterized by a layer of bottom sediments having velocities of 1.6–2.4 km/sec and averaging approximately 2 kilometers in thickness. However, on the continental slope, this sediment layer thickens to more than 5 kilometers; beyond the slope area, the thickness is again about 2 kilometers. In places, particularly south of Bahia Grande and in deep water beyond the continental slope, the bottom sediments can be divided into an upper member with a velocity of 1.6–2.0 km/sec and a lower member with a velocity of 2.1–2.4 km/sec.

Beneath the bottom sediments, a layer with a velocity of 2.5–3.8 km/sec is found in many places. This is not a continuous feature, however, and varies from zero to 2 kilometers in thickness. In many areas, this layer is replaced by one having a velocity in the range 4.2–4.9 km/sec, and in a few areas both layers are present. As with the 2.5–3.8 km/sec layer, the higher-speed layer is not continuous; it varies in thickness from zero to 5 kilometers. Both layers are probably consolidated sediments.

Beneath these consolidated sediments, crystalline rock with velocities varying from 5.0 to 6.1 km/sec is encountered. In some areas, a higher-speed horizon with a velocity of 5.9–6.4 km/sec was observed beneath this upper crystalline layer at depths of 5–7 kilometers. On a section perpendicular to the coast from Comodoro Rivadavis, the velocity in this intermediate layer was found to increase to 7 km/sec beneath the continental slope, where the layer reaches a maximum depth of 10 kilometers; the velocity then decreases as the layer rises toward the crustal surface beyond the continental slope.

The oceanic section observed at the eastern end of this traverse shows 2 kilometers of bottom sediments, consisting of a sur-

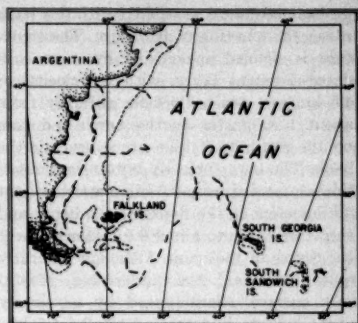


Fig. 2. Seismic Observations (short lines) in the Scotia Sea, and in the Falkland, South Georgia, and South Sandwich Islands Areas. Lighter short-dash line represents approximate position of edge of continental shelf.

ficial layer, 0.3 kilometer thick, of 1.8 km/sec material and 1.5 kilometers of material with a velocity of 2.3 km/sec; the latter lies directly on crystalline rock material 1.5 kilometers thick and with a velocity of 5.6 km/sec. Beneath this crystalline material, a layer with a velocity of 6.6 km/sec, was observed extending down to a depth of about 13 kilometers; at this depth, the Mohorovičić discontinuity, with a velocity of 8.0 km/sec, was encountered.

Scotia Sea-Falkland Islands Area: Traverses were conducted in the Scotia Sea-Falkland Islands (Isles Malvinas) area. One extended westward to South America and another southward to about 57°S (see Fig. 2). Within the South American continental shelf area, a 6-kilometer layer of sediments with velocities of 4.4–4.9 km/sec was found. This layer thins rapidly eastward and is replaced in the Argentine Basin by sediments with a velocity of 2.9 km/sec; it is again encountered, with a thickness of 2 kilometers, near the Falkland Islands.

South of the Falkland Islands, the seismic section crosses a 100-fathom-deep bank about 100 kilometers wide and 330 kilometers long. The very marked change in

geologic structure associated with this bank raises the question of its origin. The structure is defined principally by a consolidated-sediment layer, with a velocity of 4.5 km/sec, which thickens abruptly from about 1 kilometer on the north and zero on the south to 8 kilometers beneath the bank. The lower-velocity bottom sediments thicken inward from 0.5 kilometer to about 3 kilometers on the flanks of the bank, and then thin again to about 0.5 kilometer over the center of the bank. Although generally quite irregular, the underlying crustal rock surface, characterized by a velocity of 6.1 km/sec, is depressed by about 5 kilometers beneath the bank, giving an inverted picture of the surface topography.

South of the bank, normal oceanic crustal structure was observed although the water is only about 3 kilometers deep. The surficial sediments are less than 0.5 kilometer thick and lie directly on crustal material with a velocity of 6.3 km/sec, which persists to a depth of 11 kilometers. At this depth, the Mohorovičić discontinuity, with a velocity of 8.3 km/sec, was found. This pattern is similar to that observed in the Pacific Ocean, rather than to that found elsewhere in the Atlantic Ocean.

South Georgia Area: Measurements in this area included a traverse extending from about 48°S to 57°S and crossing the island arc and its associated foredeep (see Fig. 2). Although the total thickness of the crust was not mapped, it was found that the sedimentary layers and the underlying crustal layer conform to the surface relief and that each of the sedimentary layers thickens as the water depth increases. The structure pattern, in which the high-velocity crustal rocks are at a higher elevation beneath the island arc than beneath the associated trench, agrees with that observed in the West Indian arc area. Layers were observed in the Scotia Trench with velocities of 2.0, 4.0, and 5.6 km/sec.

South of South Georgia, the crust was found to have a layered structure, the

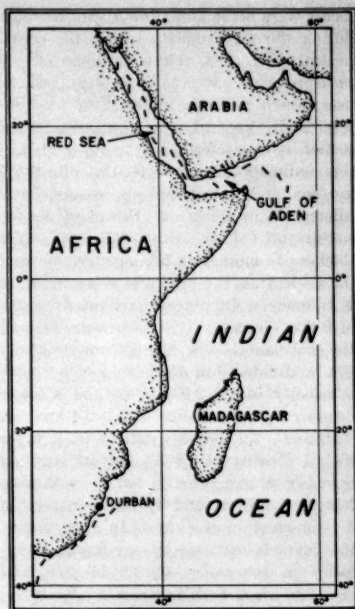


Fig. 3. Seismic Observations (short lines) in the Indian Ocean off the Coast of South Africa, in the Gulf of Aden, and in the Red Sea.

lower member of which has a velocity of 7.6 km/sec. A similar high-velocity basal crustal layer was observed in the Caribbean (see Figure 2 of *Bulletin No. 21*).

South African Area: Twelve seismic stations were occupied near the southern coast of Africa by the *Vema* of the Lamont Geological Observatory and the *Vrystaat* of the South African Navy (see Fig. 3). Although analysis of the observations at these stations is still incomplete, tentative wave velocities have been obtained. A typical mantle velocity has been tentatively identified for a station east of Durban (station no. 161). It is hoped that final results from the stations near Durban can be related to a

profile obtained inland from Durban by A. L. Hales, of the Bernard Price Institute, Johannesburg.

Gulf of Aden-Indian Ocean Area: None of the measurements carried out in this region give a measure of total crustal thickness, although velocities as high as 7.8 km/sec were recorded on reverse profiles. At all sites (see Fig. 3), two sedimentary layers, having velocities of 1.85 km/sec and 3.9-4.6 km/sec, were recognized. The total thickness of both layers varies from 2 to about 4 kilometers. Beneath these sedimentary layers, crustal material with velocities of 6.4-6.8 km/sec was found. Very-high-velocity material (7.6-7.8 km/sec) was observed at only two stations, at depths greater than 9-11 kilometers.

Because of the shallowness of the water in this region—1310-2670 meters—these values cannot be reconciled with the crustal thickness to be expected or with the results of gravity surveys, which suggest that the base of the crust here should be about 17 kilometers below sea level. The occurrence of such high-velocity material within the crustal layer is significant: in other areas, such velocities have been identified with the mantle rock beneath the crust.

Red Sea Area: In this area, a local "high" in both gravity and magnetic values is identified with a submarine trench extending through most of the length of the

Red Sea. (See Figure 3 for seismic-station locations.) Although the total thickness of the crust was not measured, the seismic values indicate the cause of the high. In the bordering shelf area, the thickness of sediments varies between 2 and 6 kilometers, except in one area near St. John's Island, where the total thickness is 10 kilometers. The underlying crust was observed to have a velocity of 5.9 km/sec. No greater velocity was detected in this region.

In the central trench area, the thickness of the sedimentary-rock layer is the same as in the shelf area (2-6 kilometers), but the underlying crustal material is characterized by a high velocity of 7.1 km/sec. As the magnetic and gravity anomalies are missing in the graben area of the Gulf of Suez and Agaba, it appears that the 7.1 km/sec material found in the Red Sea Trench is probably a body of basic rock (igneous rock consisting largely of dark-colored metallic minerals) that had originally invaded, in a molten state, a crustal fracture system in this portion of the graben. (A graben is a linear crustal block that has subsided between faults, or very large fractures, flanking it on either side.)

Mediterranean Area: Fifteen seismic stations were occupied in the Mediterranean Sea by the *Vema* of Lamont and the *Atlantis* of Woods Hole. Although velocities and thicknesses have been tentatively determined, analysis is still incomplete.

Rocket Observations of High Electron-Density Gradients in the Ionosphere

The following material was supplied by J. C. Seddon, of the Goddard Space Flight Center, National Aeronautics and Space Administration. Mr. Seddon was associated with the US Naval Research Laboratory when these experiments were conducted.

Prior to the IGY, and also as part of its contribution to the IGY program of upper-atmosphere rocket studies, the US Naval Research Laboratory launched a number of rockets at White Sands, New Mexico, and Fort Churchill, Canada, instrumented

to measure electron densities in the ionosphere. *Bulletin No. 20* presents results of some of these flights indicating significant variations in electron density with time of day, season, and latitude, and during the solar-related conditions causing the "polar blackout." Further analysis of the flight data has shown the existence of unusually high rates of change of electron density at various levels in the ionosphere. The present report discusses these high electron-density gradients and their significance in terms of ionospheric conditions.

High electron-density gradients were found in all ionospheric regions penetrated by the rockets. In the D-region (in this report, the portion of the ionosphere below an altitude of about 90 kilometers) a high gradient was almost always present near the mesopause—the top of the mesosphere, a high-temperature layer extending from the stratosphere to a height of about 85 kilometers. In the E-region and slightly above (here 90 to about 170 kilometers) high gradients were associated with sporadic-E at various levels, and in the F-region (above 170 kilometers) they appeared related to the distribution of spread-F. (Sporadic-E refers to clouds or patches of unusually high ionization in the E-region, spread-F to "blobs" of high ionization in the F-region. Both sporadic-E and spread-F result in radio propagation under unusual conditions.)

Cooperation essential to the success of the experiments was given by agencies of the US Army, Air Force, and Navy; the Canadian Northern Defence Research Laboratories at Fort Churchill; the Defence Research Telecommunications Establishment, Ottawa; and the Central Radio Propagation Laboratories, of the National Bureau of Standards, Boulder, Colorado.

Experimental Technique

To determine ionospheric electron densities along the path of a rocket, two harmonically related, unmodulated signals are

transmitted from the rocket, which is traveling almost vertically upward, to ground stations nearly directly beneath the rocket. The lower-frequency signal is separated into its magneto-ionic components; then its frequency (in this case, 7.75 megacycles) is multiplied such that it can be combined (heterodyned) with the higher frequency—46.5 megacycles. The resulting "beat note"—a periodic increase and decrease in loudness resulting from simultaneous sounding of two signals of *nearly* the same frequency—provides the index of refraction of the medium surrounding the rocket. This is then used to calculate the electron density. High electron-density gradients are indicated by rapid changes in the beat-note frequency.

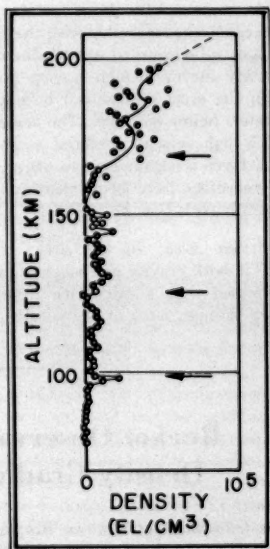


Fig. 4. Electron-Density Profile above Fort Churchill as Measured by IGY Flight NNS.11F on February 4, 1958. Arrows indicate gradients at 98, 129, and 170 kilometers.

TABLE 1
Altitude of High D-Region Electron-Density Gradients

Rocket*	Date	Launch Time (hrs-LMT)	Place	Altitude of high gradient (km above sea-level)	Remarks
V-2 No. 49	9-29-49	1000	WS**	66.7	A "quiet" day; moderately high gradient at 86 km
Viking 5	11-21-50	1018	WS	85.9, 92.0	Sporadic-E
Viking 10	5-7-54	1000	WS	74.5, 78.3, 86.0	Sporadic-E
NRL-50	6-29-56	1209	WS	86.7	Sporadic-E
NRL-47	11-15-56	1332	FC***	64.2, 65.2, 71.6, 83.5	Polar blackout
IGY NN3.08F	7-4-57	1216	FC	69.5, 82	Polar blackout
IGY NN3.10F	2-3-58	1202	FC	86.5	Quiet day; intermittent sporadic-E
IGY NN3.11F	2-4-58	0017	FC	81.6, 91.6	Sporadic-E; spread-F

* Last five were Aerobee-Hi's
 ** White Sands Proving Ground, New Mexico
 *** Fort Churchill, Canada

D-Region Observations

From the very beginning, these rocket data showed evidence of the existence, at various levels below about 100 kilometers, of very thin layers with large electron-density gradients. It was initially thought that these effects were instrumental in origin, but subsequent laboratory studies lend strong support to the conclusion that they are indeed produced by high electron-density gradients. Gradients as high as 10^6 electrons/cm²/km were found, and in one case a high gradient occurred within a vertical range of only 25 meters. The altitudes of occurrence vary from about 64 to 92 kilometers, as shown in Table 1.

There appears to be no tendency for the gradients to occur at selective altitudes, except near the mesopause. At White Sands, in middle latitudes, this persistent high gradient occurs in the vicinity of 86 kilometers, while at Fort Churchill, in high northern latitudes, it averages about three kilometers lower. These results are in

agreement with lower-frequency (1.75 mc/sec) ground observations by J. B. Gregory, who detected echoes from various heights in the D-region, including a persistent one from about 85 kilometers.

In general, the electron-density profiles resulting from the flight data are rather "spiky" in nature, with positive gradients followed almost immediately by negative gradients on the upward leg of a flight. (This spikiness is especially well illustrated in Figure 4.) The high gradient occurring near the 85-kilometer level, however, always has a low gradient immediately above it for a distance of several kilometers. Above this, in turn, the gradient again increases rather rapidly. Gregory has suggested that this high electron-density gradient near a height of 85 kilometers may result from the concentration at the mesopause of cosmic dust settling into the earth's atmosphere. Such high gradients could be caused by constituents of this dust possessing a low ionization potential.

E-Region Observations

The data from several of the rocket flights, both at White Sands and at Fort Churchill, show the presence of sporadic-E gradients (see Table 2). On some flights, sporadic-E existed at more than one level. In every case, sporadic reflections observed at the ground-based, ionosphere virtual-height-finding stations were found to be caused by the presence of very high electron-density gradients extending horizontally for many kilometers. (One such gradient had a horizontal extent of more than 80 kilometers.)

The thickness of the sporadic-E layers was generally two kilometers or less. In most cases, the increase in electron density was not great, although increases of as much as a factor of two have been observed. The data indicate some horizontal variability within the sporadic-E layers, but no evidence was found of "holes" in the layers in which electron-densities and gradients return to normal. Sporadic-E thus seems to consist of a thin layer of consider-

TABLE 2
Altitudes of Sporadic-E

Rocket	Altitudes in Kilometers			
V-2 No. 34	100			
Viking 5		109		
Viking 10	100	105	112	129
NRL-50	101		117	
IGY NN3.08F		105		
IGY NN3.10F		110		
IGY NN3.11F	98			129

able horizontal extent in which the vertical electron-density gradient has become quite large. There is also evidence that these high gradients have "preferred" altitudes of occurrence in the E-region—at about 100, 105, 110, 117, and 129 kilometers.

The data for the E-region portion of the flights do not show the same type of abrupt changes characteristic of the D-region; instead, the beat frequencies increase rapidly with altitude when high gradients are

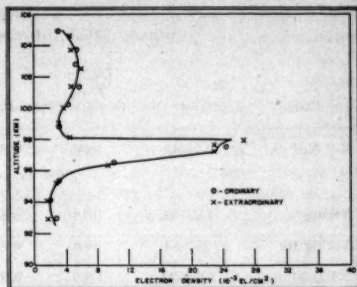


Fig. 5. Electron-Density Profile of Unusual Sporadic-E Layer at 98 Kilometers (compare with Fig. 4), Measured by Flight NN3.11F. Both ordinary and extraordinary components of refracted radio wave are shown.

encountered, and then, usually, they decrease with less rapidity. A night flight at Fort Churchill, however, showed just the reverse situation at an altitude of about 98 kilometers (Figs. 4 and 5). Moreover, in this case, a fall in density from 25,000 el/cm³ to 5000 el/cm³ took place within a vertical distance of not more than 80 meters at the top of the sporadic-E layer.

The horizontal arrows in Figure 4 indicate the location of the gradients responsible for sporadic echoes at about 98, 129, and 170 kilometers. The 98-kilometer echoes were persistent, but the others tended to appear and disappear. The 129-kilometer gradient was 600 meters thick and had a maximum density less than that at 98 kilometers. The gradients observed by the rocket on both sides of the 129-kilometer layer were smaller than the gradient on the upper side of the lower layer. When the rocket descended through the 98-kilometer layer, the extreme sharpness of gradient on the upper side had disappeared. Apparently the gradients vary rapidly with time. Not much information could be deduced concerning the 170-kilometer gradient as the data record was very erratic for this and higher levels.

F-Region Observations

For the region above 170 kilometers, the records of IGY NN3.11F, a night flight at Fort Churchill, showed a continuous series of very rapid changes in the frequency of the beat note, indicating many high gradients in the electron density. The data become extremely erratic with increasing altitude, and above 220 kilometers the record is mostly unreadable. By comparison, the record of NRL-50, launched on a relatively quiet day over New Mexico, had almost sinusoidal beat frequencies.

At 199 kilometers, the beat frequency increased rapidly on the NN3.11F flight, and the amplitude of the signal decreased extremely rapidly (see Fig. 6). Signal

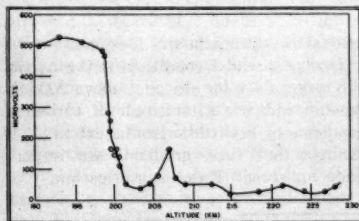


Fig. 6. Amplitude of Ordinary Component of 776-Megacycle Signal from Flight NN3.11F as it Penetrated Spread-F Region. Note great drop in signal strength at an altitude of about 200 kilometers.

strength fell 20 decibels in a height interval of a few kilometers. Hence, the lower edge of the F_2 -layer, the uppermost of the two layers of the F-region, was probably at this height and had a very high electron-density gradient where penetrated by the rocket.

The rocket had a horizontal velocity of about 150 meters per second, and 80 seconds after the 199-kilometer gradient had been penetrated the signal amplitude increased considerably. Thereafter, during the rocket's descent, the amplitude varied irregularly from high to low values and did not again show the sharp change that had

occurred at 199 kilometers on the ascending leg. The 7.75-megacycle voltage on the antenna did not change appreciably during this time. These data indicate the existence of numerous very high gradients over a limited horizontal distance in the F-region during spread-F conditions.

Shortly after reaching peak altitude (234.5 kilometers), the radial velocity of NN3.11F with respect to the ground station became zero. The beat frequency did not also fall to zero, however, but instead continued very complex. This indicates that the atmospheric ionization below the rocket was undergoing considerable variation with time. Figure 7 shows the very irregular amplitude of the 46.5-megacycle signal near peak altitude, compared with the relatively smooth character of the signal when the rocket was about 18 kilometers lower. A ground-based interferometer at this frequency, with 122-meter baselines, showed phase excursions of about ± 20 minutes of arc, with occasional sudden changes of as much as one degree of arc. Such severe phase changes had never before been found in rocket data.

Conclusions

Rockets instrumented for ionospheric observations prior to and during the IGY by the US Naval Research Laboratory recorded the existence of many high electron-density gradients between heights of about 64 and 200 kilometers in the ionosphere.

The presence of such high gradients in the D-region was detected by every NRL rocket launched in this series of investigations. Between heights of 64 and about 92 kilometers, these gradients are very thin and are located at various altitudes, except for a persistent one near the mesopause. The mesopause gradient usually exhibits a step-increase in electron density during the day, with a low gradient just above it.

E-region gradients, which are responsible for the sporadic-E echoes noted on ionograms, cover a large horizontal area and are usually thicker than the D-region gra-

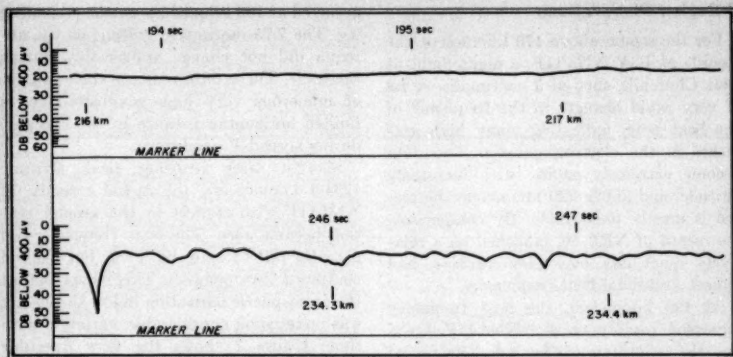


Fig. 7. Amplitude (in decibels below 400 micro-volts, μv) of 46.5-Megacycle Signal from NN3.11F Showing Effects of Spread-F. Near peak altitude, the signal is very irregular; 18 kilometers lower it is smooth.

dients. However, none has been found thus far exceeding two kilometers in thickness. The maximum electron density is usually not much greater than the normal density in the E-region, but an increase by a factor of two was observed. The existence of a polar blackout was not found to alter the

general conditions in the E-region.

During spread-F conditions in the Arctic, the rocket data for altitudes above 200 kilometers indicate a multitude of turbulent gradients of limited horizontal extent. It is thought that these gradients are responsible for spread-F radio propagation.

Determination of Past Antarctic Climate by Thermoluminescence of Rocks

The following material was prepared by E. J. Zeller and W. C. Pearn, of the Department of Geology, University of Kansas.

Certain minerals characteristically emit visible light when heated—a property called thermoluminescence. Studies of thermoluminescent minerals can provide information about past temperature environments of the minerals and of the rocks in which they are found. As part of the IGY program, Antarctic rock samples were collected and analyzed by E. J. Zeller and W. C. Pearn. From their thermoluminescence characteristics, it was possible to estimate an approximate upper limit for rock temperature

in parts of Antarctica in the geologically recent past. It was also possible to make tentative inferences regarding past climatic conditions, in particular the minimum length of time that Antarctic climate has been frigid. This report concerns these studies and findings.

Theory

Light is emitted from a thermoluminescent mineral by the release of energy when electrons move from "trapped" to normal positions within the mineral's crystal lattice. Theoretically, imperfections in the lattice resulting from negative ion vacancies

or from impurity ions included within the crystal structure constitute electron traps. Ionization induced by high-energy radiations, particularly from alpha particles emitted by radioactive impurities in the mineral, causes electrons to be displaced into these electron traps from their normal positions in the crystal lattice. At very low temperatures, such electrons remain trapped and others continue to accumulate in the traps. When the temperature is raised, the electrons are released from the traps and return to their normal positions, causing light to be emitted.

Thus, the accumulation of potential thermoluminescence depends on both the natural radiation rate to which the mineral has been subjected and the temperature of the rock during the period of accumulation. The former is a measurable quantity in most carbonate rocks, including the Antarctic limestones and marbles used in the present study; the latter is an unknown quantity related to the thermal history of the rock sample during the period of accumulation of the thermoluminescence. This thermal history is influenced by depth of burial of the rock, by snow or ice cover, and in some areas by circulation of groundwater. Only in terms of long-range averages, however, can any inferences about actual atmospheric temperatures be made.

The entire process of accumulation and release of thermoluminescence can be approximated in a short time in the laboratory by subjecting a rock or mineral sample to high-intensity radiation, followed by heating. The thermoluminescence properties of rock or mineral samples are represented graphically by glow curves and decay curves. Glow curves are graphs of the variation of light intensity with temperature. Peaks in the glow curves represent temperature levels of maxima in the intensity of the light emitted. Decay curves are graphs of the decay rate of glow curve peaks when the sample is heated at a steady temperature. Comparison of the graphs for natural samples with those for

portions of the same samples irradiated artificially permits inferences about the thermal history of the rock in its natural habitat.

Calclitic limestones and marbles from temperate climates, but otherwise similar to the Antarctic samples used in this study, usually show glow-curve peaks at 235° C and 310° C. In many of the Antarctic samples, another peak, small but distinct, was found at 125° C (see Fig. 8). It was originally planned to use the 235° C peak in these investigations, but the low-temperature peak at 125° C was found to permit simplification of procedures and increased accuracy in computations. The 125° C peak is sensitive to smaller changes than the 235° C peak within the temperature range considered to be of climatic significance.

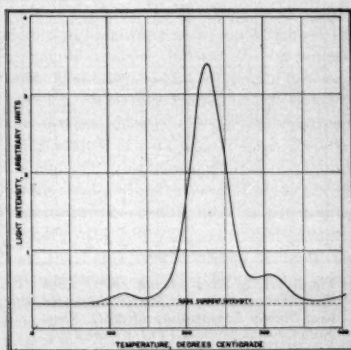


Fig. 8. Typical Glow Curve for an Antarctic Carbonate Rock Sample. Note light-intensity peaks at 125°C, 235°C, and 310°C.

Procedure

From November 6 to December 3, 1958, a total of 46 carbonate-rock samples suitable for thermoluminescence studies were collected in the McMurdo Sound region of Antarctica. Samples were obtained from four localities in the Marble Point area and from two localities near Taylor Glacier. Al-

though samples from both areas showed low-temperature thermoluminescence, those from Marble Point were judged more reliable.

All samples were collected in duplicate. A smaller portion of each sample was shipped to the University of Kansas packed in dry ice, while larger portions were shipped back on the same flight but were not kept cold.

To determine the decay rate of the natural peak at 125° C the samples were held at a temperature of 25° C (77° F). At selected time intervals, glow curves were run on small, representative portions of the samples. The maximum light intensity for each glow curve was then used to plot a decay curve for each sample. Figure 9

samples did not show the 125° C peak. This can probably be attributed to the effects of very recent solar heating on exposed rock surfaces.)

The use of temperatures other than 25° C would have led to a comparable result since there is a consistent, inverse relationship between temperature and thermoluminescence decay time: the higher the temperature the shorter the decay time, and vice versa. The choice of 25° C was a matter of convenience. At 25° C, the time required to reduce the natural thermoluminescence to zero (125 hours) is neither too long nor too short to be conveniently used for laboratory observations. Moreover, 25° C is close to what might be considered a temperate, if not tropic, climatic temperature, and is therefore suitable for comparison with the frigid conditions necessary for retention of thermoluminescence.

Because of individual variations in composition, it was necessary to calibrate each carbonate sample to determine its efficiency for storing energy in the form of thermoluminescence. Each sample was first held at 100° C until all of its natural low-temperature thermoluminescence was drained off. Three small, representative portions of each sample were then subjected to increasing increments of gamma radiation from a source of known intensity (Cobalt 60) in order to relate the radiation dosage to the build-up of thermoluminescence. Next, glow curves were run for each portion of the sample, and the areas under the low-temperature glow-curve peaks were measured and plotted on a single graph against the amounts of gamma radiation received. The result was the calibration curve for the sample. Calibration curves can be used to determine the gamma-radiation dosage equivalent to the natural alpha-radiation activity required to produce the sample's natural thermoluminescence.

These and previous studies seem to indicate that an artificial gamma-radiation dosage of 1000 roentgens is equivalent in thermoluminescence-producing capacity to

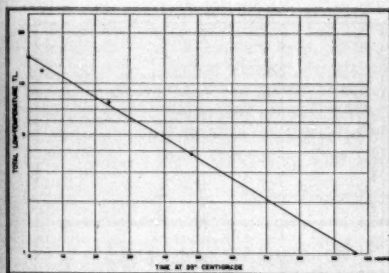


Fig. 9. Decay Rate of the 125° C Low-Temperature Peak of Sample Subjected to a Steady Temperature of 25° C. Thermoluminescence units (TL) are arbitrary.

shows a typical decay curve for one of the Marble Point samples. This curve indicates that at 25° C the half-life for the natural 125° C peak is approximately 25 hours. After five half-lives the remaining thermoluminescence is about equivalent to the threshold sensitivity of the apparatus. Thus, it is inferred that in the Marble Point area the rock temperature at depth could not have remained as warm as 25° C for a period of 125 hours at any time in the recent past. (About half of the refrigerated

a natural alpha-activity rate of one alpha particle per hour for a period of 2.5 million years ($1000 \text{ r} = 1 \text{ a/hr} \times 2.5 \text{ my}$). However, the natural alpha activity of the samples tested, as measured by scintillation counting techniques, was found to be 14.5 alpha particles per hour. At this greater alpha-activity rate, the time required to produce the observed thermoluminescence is 0.17 million, or 170,000, years.

Conclusions

The above procedures and calculations yielded four important thermoluminescence values: the natural low-temperature thermoluminescence of the sample, the gamma-radiation dosage necessary to duplicate the natural thermoluminescence, the equivalent alpha dosage, and the natural alpha activity. From these values it was possible to calculate the length of time required for the natural alpha bombardment rate to have produced the observed low-temperature thermoluminescence. For the most thermoluminescent sample from Marble Point, the calculation yields a value of 170,000 years. Hence, at least this much time has elapsed since Antarctic temperatures fell low enough to permit accumulation of electrons in the 125°C traps.

This calculated age can be accepted only if certain implicit assumptions are granted: first the transition from temperate to frigid conditions must be assumed to have been relatively rapid; second, since it is necessary to assume complete retention of all electrons once they reached the 125°C traps, subsequent major fluctuations in environmental temperature must be ruled out. However, it is possible—even probable—

that the onset of frigid conditions was not rapid. Furthermore, analogy with Pleistocene continental glaciation in the Northern Hemisphere suggests that average temperatures may not have been continuously low from the initial freeze-up to the present.

In addition to the above assumptions, certain sources of error may bear on the results. These sources of error fall into three principal categories: (i) those involved in collection of samples, (ii) those inherent in the measuring instruments, and (iii) those concerning theoretical uncertainties.

It is thought that exposure to solar heating may have caused drainage of thermoluminescence in about half the samples collected for the above study. More careful collecting methods will help correct this difficulty in the future. However, it is probable that minor fluctuations in the past Antarctic climate will continue to escape detection no matter how sophisticated the technique becomes. It must also be remembered that temperature inferences based on thermoluminescence measurements relate to the thermal history of only a relatively small sample of rock from a single locality. In addition, instrumental and procedural errors resulted, in the present study, in an uncertainty of about 12% in the alpha-activity rate. Moreover, other data suggest that the figure of 2.5 million years in the gamma-dosage—alpha-activity relationship may be low by a factor of two, or high by a somewhat smaller factor.

For the most part, the assumptions and sources of error discussed above tend toward a lowering of the calculated age. Hence, 170,000 years may be considered a *minimum* value for the time elapsed since Antarctica became cold.

IGY Bibliographic Notes

This is the nineteenth of a series of bibliographic notes on IGY and IGC-1959 programs and findings. The references are selected largely from a bibliography under preparation in the Science and Technology Division of the Library of Congress. (An interim IGY bibliography, covering the period January 1951-August 1958, prepared by the Library and published by the Academy with support of the National Science Foundation, is available from the Academy, 2101 Constitution Avenue, N.W., Washington 25, D. C., for \$1.00. The 64-page volume contains 704 references.)

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